ELECTRICAL ENGINEERING

AIEE NORTH EASTERN DISTRICT MEETING, BOSTON, MASS., APRIL 19-20, 1944

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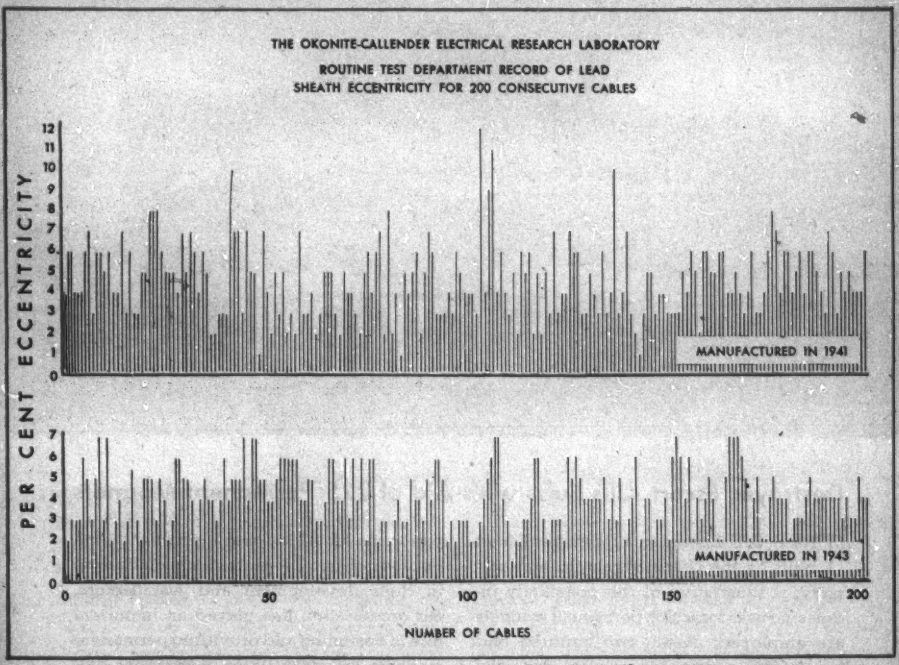

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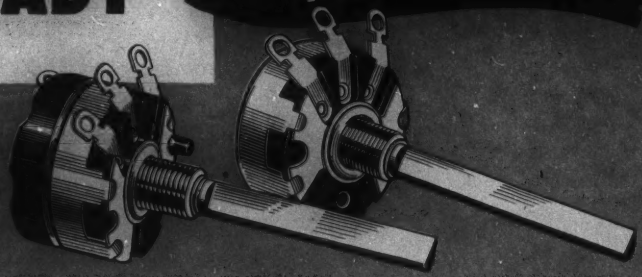

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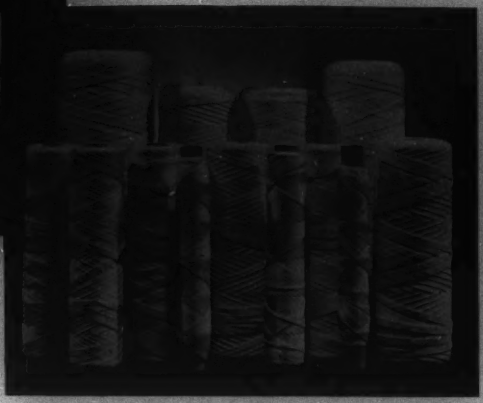

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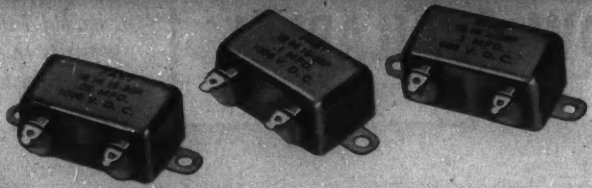

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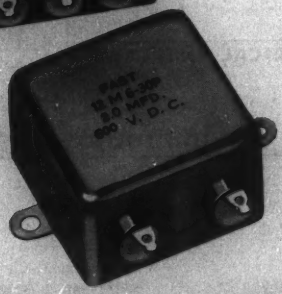

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ELECTRICAL ENGINEERING

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MARCH
1944

The Cover: New 50,000-kw Mystic generating station of the Boston Edison Company

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VOLUME 63
NUMBER 3

Statements and opinions given in articles and papers appearing in *Electrical Engineering* are the expressions of contributors, for which the Institute assumes no responsibility. ¶ Correspondence is invited on all controversial matters.

Published Monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Founded 1884

NEVIN E. FUNK, President H. H. HENLINE, National Secretary

PUBLICATION COMMITTEE: H. H. Race, *chairman*; C. E. Dean; F. Malcolm Farmer; H. H. Henline; K. B. McEachron; John Mills; F. H. Pumphrey; C. F. Wagner; S. B. Williams

Electrical Engineering: Copyright 1944 by the American Institute of Electrical Engineers; printed in the United States of America; indexed annually by the AIEE, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London). Address changes must be received at AIEE headquarters, 33 West 39th Street, New York, N. Y., by the 15th of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge.

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ELECTRICAL ENGINEERING

VOLUME 63, NUMBER 3 MARCH 1944

A Postwar Economy for the United States

WILLARD CHEVALIER

MORE AND MORE of our American businessmen must become interested in the necessity of doing some postwar planning, of doing it now, and of being prepared to put those plans into effect just as quickly as possible when the time comes.

Postwar planning is one of the aspects of this period of our war development that had no counterpart during the first World War. Perhaps the reason we were not over-concerned with postwar planning was that our post-Armistice discussions showed none of the misgivings and spirit of defeatism that exists today.

The outcome of the struggle between the collectivists and the individualists will be determined by the people of the United States on the basis of the performance of business during the first few years after the war, says this author. A high-level employment, a high-level production, and a high-level efficiency are the three standards he recommends as the foundation of an expanding postwar economy.

This time we seem to be surfeited with defeatism. We start off with the assumption that there is bound to be tremendous unemployment, and we talk about endless panaceas to cope with this inevitable unemployment. Why? What is the reason for the difference?

During the decade preceding our entrance into the war we had been suffering from an utterly abnormal depression of the American spirit as well as of the American economy. We cried out for all sorts of needles to stimulate us once again, but none of the needles seemed to work, because the patient himself had lost so much of his vitality. Now with a situation so different from what it was during the 30's, as we approach a period of enormous accumulated shortages and enormous available purchasing power, we are still living in the psychology of defeatism that governed us in the 30's. Instead of looking forward to the opportunities ahead, we are brooding over the problems that bothered us during the 30's and wondering what we are going to do about them when the war is over.

COLLECTIVISM VERSUS INDIVIDUALISM

One of the reasons we have lost our faith to such a degree in the spirit of American enterprise and the opportunities of American life is that for some 15 years throughout the world there have been a great many outbreaks of a doctrine of collectivism as a means of regularizing and controlling the economic life of nations.

This doctrine of collectivism has appeared under many different forms in many lands. One of them was the refurbished tinsel Roman imperialism of Mussolini under the name of Fascism. Another was the vast Wagnerian racketeering of Hitler and his Nazi clique. Even our professional brethren discovered their particular form of collectivism all wrapped up in a technical Mumbo Jumbo of one kind or another. Collectivism in some form or another seemed to have taken hold of people the world over as an easy way out of their economic troubles.

However these outbreaks may have varied in their superficial terms, they had one aspect in common. That was the existence of a small, self-appointed, and self-perpetuating group of know-it-alls who were prepared to plan the economy and direct the productive energies of the rest of the people in their society, be it nation, community, or whatnot. That little group of know-it-alls was the common denominator of all these various forms of collectivism.

There may well be a justification for this collectivist phenomenon in order for example, to shift a nation such as Russia bodily from the agricultural peasant economy of centuries to a new industrial economy, in the shortest possible time. Or when a nation stands with its back against the wall and must fight a war, for either defense or conquest, and all the productive energies of a nation must be mobilized for the one purpose of waging war under the single-minded direction of a government, then, too, there is a place for collectivism—indeed, a very essential place.

But it does not seem that this collectivist concept has had anything to offer the American people that would be superior to what they have had now—that is, the philosophy that has produced an Edison, a Westinghouse, a Doctor Bush, and all the rest of those that we, as engineers, delight to honor.

However, this issue of individualism versus collectivism is very much in our minds today. A large part of the defeatism, this uncertainty and worry about what the postwar period is going to bring us, arises from the fact that the war began during this debate of the '30's, and a great many of us are not yet quite sure what will be the outcome of that debate in the minds of the American people. We are beset by an uncertainty and a concern that grows out of this issue of individualism versus collectivism.

Essential substance of an address delivered at the general session of the AIEE winter technical meeting, New York, N. Y., January 26, 1944.

Willard Chevalier is vice-president and director of McGraw-Hill Publishing Company, Inc., New York, N. Y., and publisher of *Business Week*. He served as lieutenant-colonel of the 11th United States Engineers during World War I.

I have a feeling that the first few years following this war are going to determine that issue for at least a generation, or maybe two generations or more, in the United States. The significant thing to us, as businessmen on the one hand, and engineers on the other, is that this issue will be settled not by any debate on ideology but on the cold stark basis of performance. And the judges who will sit in judgment are the people of the United States, not the professional groups, not the business groups, not the industrial groups. The issue will be determined by the American people, on the basis of the performance of the first few years following the end of the war.

THE COLLECTIVIST'S HAND

Now then, let us take a look over the shoulders of both parties to this controversy and see what kind of cards they hold. When we look into the hands of our collectivist friends, we find that the best cards they have are the undoubted deficiencies and abuses that have grown up in the conduct of business, especially corporate business, over the years—deficiencies that have tended to limit competition, restrict production, and prevent our system from delivering the largest possible benefit to the greatest number of people. I do not imply for one instant that that end was deliberate or intentional, but, nevertheless, there were in the operation of our system, certain practices that needed corrections.

Another face card in the hands of the collectivists was the collapse of 1929, the enormous mass employment, the great human distress that came about from what they are pleased to call the collapse of our system. I am not underwriting that description. I am merely quoting it.

Another high card they have in their hands is the punitive measures of regulation, taxation, and employment, that resulted in the '30's from public resentment at the distresses that we were called upon to bear as a result of the collapse of '29. Those who deal in the commodity of politics are always ready to make hay out of whatever they may find growing, and, if they find resentment, unhappiness, and misery then these become the things to harvest and make hay of. Lord knows there was plenty of hay made out of the resentment of the American people during the '30's. We had a state of regulation, control, statutory enactment—much of which was salutary, some of which was overdue, but a very large part of which was purely punitive in its intent and in its effect upon the operation of our system.

Another face card in the hands of the collectivists is the concept of the mature economy, the idea that we had gone as far as we could go, and from now on we would have to administer more and more closely and regulate more and more rigidly all of the little trickle of resources that we had already developed in the United States.

And then another high card in the hands of the collectivists is the increasing political power that they have succeeded in gathering over these years as a result of these developments of which I have already spoken. And another, of course, is the fact that we have been compelled to invoke a collectivist economy for the purpose of waging war, and the question comes up "If it does a good job in war, why shouldn't it do a better job in peace?"

Finally, we have the very large Government investment in the various forms of productive activity, again as a result of the war, which puts a card into the hands of our collectivist friends. When you add all of the accumulated worries and uncertainties that beset the industrialist and the businessman of today, as he contemplates the future and tries to bolster up his courage to the sticking point to fulfill his traditional role as the risk taker, the adventurer, the economic explorer, you see that our friends, the collectivists hold a fairly strong hand.

Now let us take a look at the hands of our friends who do not believe it's necessary to have recourse to collectivism to salvage America after the war.

THE INDIVIDUALIST'S HAND

The individualist's hand has its face cards, too. In that hand is the best ace in the deck—that the American system, for all its defects, its deficiencies, its theoretical puzzles, and its practical abuses, has given the American people the highest standard of living that any people, anywhere in the world have ever enjoyed.

Another big card is the record of industry in this war and the altered public attitude toward industry as a result of its incomparable achievements in the war. I remember so vividly in the early days of our defense effort how fearfully American industry was on the defensive. I remember the vicious and vitriolic charges that were thrown against it for its profiteering and its unwillingness to go all out for war and its efforts to evade its responsibility. It seems hard to believe that that was only a couple of years ago when we contemplate what has happened since.

Another high card is the fact that we have had an enormous acceleration of technical progress during the war. Our technicians have given us new powers with which to work. Our industry has new tools with which to tackle this postwar job.

Another high card is the reactivated confidence of industry in its own productive capacity. We have a new faith in ourselves, a new belief. We have the complete answer to the notion of the mature and finished economy that is bumping up against the ceiling of its potential. We have pushed that ceiling up until it has disappeared into the ethereal, and today the American businessman and industrialist recognize no limitations upon their productive capacity if the conditions and the demand be right for them to go ahead.

And then another high card that I see is the political reaction that we have among the American people against the excesses of the extremists who find themselves in power and who try to sell the collectivist bill of goods.

But the biggest card, next to that one outstanding fact of the accomplishment of our system, is that the American people are coming to understand what is meant by a planned economy. They are beginning to learn that economies cannot be planned in a vacuum, but only in the lives of the people who live under those economies. They have been brought up on the notion that a planned economy implies only that industry and the businessman will be planned, and that Joe Doakes, Mrs. Doakes, and the little Doakes will go on being just the same kind of American Doakeses they always were. Now they are beginning to realize that, when the planner begins to plan an economy, he has to plan the production of that economy. That means he has to plan where Joe will work, what he will produce, how long he will work, and what he will get paid for it. And even more, the planner will plan what Joe can buy when he goes down to Main Street with the dollars that the planner has given him for

putting in his time working on what was planned. Joe is beginning to realize, in other words, that economic planning includes him.

Now the American people are alive to what a planned economy means, and they do not like it. They are perfectly willing to put up with it for the sake of winning a war, but they want to get it over with so that they can get back to living their American lives.

And, incidentally, a high standard of living is not necessarily just a matter of having an abundance of material things, not nearly so much as having the complete freedom of choice as to what you as an individual will choose from this great abundance. What constitutes one of the elements of the American standard of living is that when you go out you can get what YOU want.

THREE YARDSTICKS

These are the cards that are held in the two hands. What are the yardsticks by which the American people will judge the performance? The first of these, in my judgment, is our ability to deliver a high level of employment in this country, a sustained high level of employment. I do not mean full employment. You can insure full employment only by means of a totalitarian planned economy. This does not necessarily mean that the same people are always unemployed, but there will always be a measure of unemployment. When we talk about and promise full employment, we are talking about something different from the operation of a free people and a free economy.

What I mean by high level of employment is that we must have a scale of employment, a level of employment, so high that there will be no distress unemployment, that there will be no feeling of mass insecurity on the part of a large number of our people that they are not going to be able to get jobs when they want them. And we must remember that our employment must be on a scale that will furnish opportunity for the individual who wants, and is able, to rise above the mass, to reach to higher levels of compensation and higher standards of living. We want a scale of employment that will enable us to realize those two ends: no feeling of mass insecurity as to distress unemployment, and still opportunity for the individual to rise, because he shines in abilities and skills in comparison with his fellows.

The second yardstick by which, I think, our people will judge our performance is a high level of production. Too much emphasis has been placed in recent months upon this matter of high-level employment and not enough on high-level production. After all, it will not help our unemployment problem to add the names of people to payrolls, either public or private, unless they are putting their energies into producing the things that are needed in order to maintain their standard of living.

Simply putting people to work rolling peanuts down Main Street and putting their names on payrolls will not solve the unemployment problem, because it will not give the people the things they need whereby to live. A high level of production is essential, because no people ever enjoyed a standard of living beyond their own production. There is no source of production except the brains and the labor and the work of the people themselves, and, if any individuals think that they, by any process of payroll legerdemain, are going to be cut in on the things that they did not produce, then they are simply taking away from someone else the things that he produced. There is no magical source of the things that people want except through their own efforts and their own labor. And so I put a high level of production as the second yardstick by which our people must judge performance.

And then the third is a high level of efficiency, higher perhaps than we ever have known. Efficiency in the sense of a greater amount of production of the things that the people need in terms of expenditure of human effort. We will have to carry an increased burden after this war. The only way one can carry an increased burden is by putting more value underneath it, and the only way to put more value underneath it is to make the expenditure of human energy count for more in the production of real wealth. Only in that way shall we be able to cope with the burden the war will leave us.

This high level of efficiency touches all five of the elements of our economy. First, it touches capital. Capital must realize that the time is past when, we in the United States, can afford to get rich by the simple process of multiplying pieces of paper. We must realize that if capital is to expect a return, capital must apply itself to truly productive effort in increasing our efficiency, that we cannot hope to build fortunes nor to get reasonably rich nor to accumulate competences merely by multiplying a number of pieces of paper that represent the extent of wealth. Capital must be efficient if we are going to have an efficient economy.

Next, technology must be efficient. We must press back inexorably, unremittingly, the frontiers of our scientific knowledge, and we must put that science to work just as fast as we can do it. We cannot have any holiday in the application of our scientific progress to the doing of useful things in the economy of which we are a part. Science must work, science must be efficient, and science must be employed continually in solving the problems that will confront us.

The next element that must be efficient is management. Management must lay aside the idea that it will prove its prowess by conserving what it has. It must be bold and aggressive and press forward always to new accomplishment, to new production levels, to new distribution triumphs of one kind or another. The idea of a conservationist management must be discarded if we are to achieve the high efficiency necessary to carry the postwar load.

Labor must learn that it too must contribute to efficiency. We must get out of the head of the American workman the notion that if he gets more out of the boss and gives him less he is putting something over on the boss, because when he gets more for doing less he is getting the best of no one but himself. In the long run he is going to have only what he produces, and, if he consistently works it out to get more laundry checks in his hands for producing fewer shirts, he is the one who will lose his shirt. We must get over the idea of restricting output in the fallacy that somehow or other we are helping ourselves in doing it; must learn that productive capital must be matched by productive labor, and that we must expect to get out no more than we put in. We can get more only by producing more and doing more.

Finally, we must have a Government policy that through taxation, through every means of regulation and control that it has, will stimulate the obsolescence of the

old and the development of the new. If we are to expect capital to accept the obsolescence of the old that goes with constant improvement, then we must have a recognition of that policy through taxation and other regulatory policies of government. A premium must be put upon the adventurer, upon bold capital rather than timid capital, upon aggressive management rather than conservationist management. If we are to achieve this high efficiency, we must have highly efficient government policies as well as highly efficient business policies.

The responsibility of the engineer touches all of these. It is perfectly obvious that it touches technology. There is no need to dwell on that. It touches management less directly perhaps, but it is going to touch it more and more, because more and more the engineering attitude is going to pervade the decisions of management.

And so I say there are three yardsticks: a high-level employment, a high-level production, and a high-level efficiency, by which we are going to perform and on which performance the American people are going to judge us.

EXPANDING ECONOMY

It is 25 or 35 years since we have had a really great industrial expansion and renaissance in this country. But we will have to get back to that constant industrial expansion if we are to do the job that confronts us.

The basis of that job will be technical progress and higher efficiency in both production and distribution. Let me call the roll very briefly of the things that we will have to do and the parts into which this problem breaks down. You can write the engineer into each one of these in accordance with what measure you think he belongs there:

1. The development of new products.

2. The improvement of old products, in my judgment even more important than the development of new ones. Much emphasis is put upon these new products. But we are not going to build the American economy on all new products. It is the improvement of the old products, many of which, when improved, will be able to hold their competitive position even against the new ones, that will constitute an enormous part of the expansion of our enterprise.

3. The use of newly developed materials that have been strategic for the purpose of the war and that, sooner or later, will be released for use of civilian industry.

4. The development of constantly lower prices—in spite of all the elements of higher costs—in order to broaden our markets and to put more things within the reach of more people. That is one of the essentials of an expanding economy.

5. Modernized techniques will be necessary to make a competition more aggressive than we ever have known. If we are to throw the wraps off competition in American industry today, we will need the utmost resources of the engineer's genius and skill in order to pit producer against producer in giving the American people more for their dollars.

6. Speeded-up research, on a scale that we never have dreamed of before, research that will be made available to the small producer and the small industrialists, as well as to our great industrial organizations, is needed. And by that I do not mean Government-dominated research either. I mean research that will still be on its own as one of the exemplars of individual enterprise and individual opportunity.

7. The higher obsolescence of tools and techniques. We are going to have to learn that we have a vested interest in preserving just exactly nothing of the tools and techniques in an industrial economy. We shall have to learn the philosophy that, when we send the sales manager and the production manager out of one door with a new product, we will call in the research man and the designing engineer from another door and say "put that thing out of business just as quickly as you can, before our competitor puts it out of business for us." And we shall have to recognize that nothing has a right to exist until it can continue to compete in a free market for the preference and favor of the American people.

8. We shall have to develop merchandizing and distribution that will seek to foster the wider use of products and to broaden the markets rather than, somehow or other, to elbow out everyone else from the market. In other words, we must learn how to merchandise and distribute our products by baking bigger pies instead of by merely getting a bigger cut for ourselves. That is one of the essentials of an expanding economy.

9. Finally, a new concept of public and labor relations will be an essential of this expanding economy, because, as I have tried to suggest, it will be exceedingly difficult for any of us to develop an expanding economy in the United States if we do not have with us the technicians, the industrial managers, the working men, the Government, and the people at large. Just as long as any one of those elements is holding back, we will not be able to achieve the kind of an expanding economy necessary for us to meet the challenge of the postwar period.

I have not said a word as to just where the engineer fits into this picture. You know the answer to that as well as or better than I do. All that I have tried to do is to paint a picture of a situation and to throw out a challenge to professional engineers to rise to take the greatest possible place in that picture.

Edison's Dream

February 11 commemorated the 97th birthday of Thomas A. Edison, one of the greatest of Americans and the supreme inventive genius of the industrial age. The staggering list of his inventions compels us to realize the extent of his contribution to the United States and to the world, not merely in our own days, but for all time to come. Already he has, through the disciplined activity of his ideas, produced billions of dollars of new wealth.

Much more important than the new material wealth which his inventions have brought forth are the new paths in the pursuit of human happiness indicated by them. He sought the secrets of nature and devised the means to exploit these secrets in order that they might be applied for the betterment of man. What seemed even more important than genius was his extraordinary capacity for unflagging hard work, which led him to "scorn delights and live laborious days." He refused to accept at any time the idea of defeat and regarded the failure of an experiment as merely an incitement to further effort. He believed with the poet that "we fall to rise, are baffled to fight better."

His life and example give us courage to make a better world, to turn our increasing control over nature away from the works of destruction into the labor of creation, away from ugliness into the development of beauty. We learn the secrets of swiftness, power, and light, utilizing unseen forces hitherto hostile and deadly, to make life not merely safer and easier but also more complete. That was his imaginative dream.

Excerpt from Edison broadcast, February 11, 1944, by Charles Seymour, president, Yale University, New Haven, Conn.

Vannevar Bush—1943 Edison Medalist

THE AIEE's highest honor, the Edison Medal, was awarded for 1943 to Doctor Vannevar Bush (F '24) president, Carnegie Institution of Washington (D. C.), and director of the Office of Scientific Research and Development, for "his contribution to the advancement of electrical engineering, particularly through the development of new applications of mathematics to engineering problems, and for his eminent service to the Nation in guiding the war research program."

Presentation was made at a special session of the 1944 winter technical meeting of the Institute, New York, N. Y., January 26. Chairman W. B. Kouwenhoven of the Edison Medal committee outlined the history of the medal, which was established by a group of friends and associates of Thomas A. Edison to serve "as an honorable incentive to scientists, engineers, and artisans to maintain by their works the high standard of accomplishment" set by Edison himself, and which is awarded annually by a committee of the AIEE to a resident of the United States or its dependencies or of the Dominion of Canada "for meritorious achievement in electrical science, electrical engineering, or the electrical arts." The qualifications of the medalist were described by AIEE Past President Frank B. Jewett (F '12). Presentation of the medal and certificate was made by President Nevin E. Funk, who presided at the ceremony.

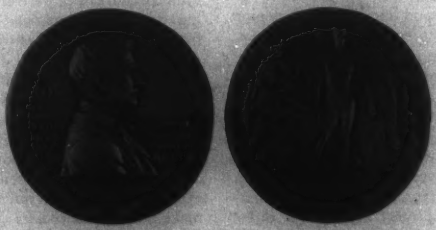
Essentially full text of Doctor Jewett's address and Doctor Bush's response follows.

The 1943 Medalist

FRANK B. JEWETT, Past President AIEE

If any of you, at the conclusion of my remarks, feel that I have handled the presentation of the 1943 Edison Medalist in an unconventional manner, I can only reply that Doctor Bush is a somewhat unconventional man. Further, for more than 25 years my association with him has been far from conventional.

When one looks over the names of the 33 men on whom the AIEE has bestowed its highest honor since the first presentation to Elihu Thomson in 1909, it is as though there were unrolled before him a moving panorama of the development of electrical engineering and the great industries to which it gave being. Here, roughly, in proper sequence of time, are the names of men who in their day made noteworthy contributions to one or another of the varied components of which the intricate structure of applied electricity is built. The scientist and teacher, the mathematician, the industrial-research director, and the great inventor are mingled with the great engineer as we commonly think of him—the man who combined several claims to our homage—and others whose great contributions were the creation of vast industries in the field of applied electricity to serve the needs of society.



Edison Medal, highest award of the AIEE, established February 11, 1904, and presented for the first time in 1909

From the vantage point of a greater distance of time it may seem, in some cases, that here and there a man was denied too long the honor of his award. In a way, however, the delay was testimony to the lasting value of his contribution.

For those of us who knew these men intimately the individual pictures thus conjured up are not so much pictures of scientific or technical achievements as pictures of men against a background of their work and the influence they exerted. Generally, the background is like that of a New England landscape—many modest hills and pleasant valleys. Occasionally, however, it is austere, and one in which a high peak or two dominates the scene and tends to deflect attention from the man toward one or more of his outstanding contributions.

Into this kaleidoscopic pattern of our recognition that men of many talents in many fields have contributed signally to the warp and woof of our profession, it is particularly fitting that we should add the name of Vannevar Bush and that we should add it at this time. As scientist, teacher, inventer, designer of powerful mathematical tools which have lightened the burden and expanded the possibilities of engineering generally, and as a distinguished director of scientific research, he has earned for himself not only a high place in the ranks of American scientists and engineers but likewise, and justly, the right to be the nation's scientific leader in this time of great national danger.

So varied are the fields to which he has turned the attention of his fertile mind, and so uniformly has that attention served to enrich them, that a poll among those who know him and his work would develop a startling diversity of opinion as to first place in the order of his claims to distinction. One has but to go through the titles of his published papers and addresses and the long list of his patents to be impressed by the catholicity and power of his mind. Those of us who know him well, however, know that the published record represents but a small fraction of his diversified interests. There is little or nothing in this published record of his equipment for automatically regulating the proper sprinkling of plants in a greenhouse; of his experiments in photography and with viviparous tropical fish; of his prowess as a navigator and skipper of ocean racers, or in the scientific commercial raising of turkeys. These and many others, I suspect, he looks upon as relaxation avocations.

If you are interested in forming an appraisal from the permanent record you must supplement the list of his scientific and technical work—largely in the field of electricity and engineering—by his contributions to technical education and its administration. You must read his reports on the patent system, his testimony before Congressional committees, and, above all, his annual reports as president of the Carnegie Institution of Washington.

It is a far cry from the ability required to design apparatus for transferring heat mechanically, or a lubricating system for vehicle wheel bearings, to that required to conceive and design the most powerful mathematical engine ever devised. By all customary standards it is a farther cry still from the type of mind which can devise a new electronic tube or a complicated radio set to one which can administer and direct creatively a great diversified fundamental science undertaking like the Carnegie Institution. Beyond that even is the greater gap which separates the quiet of the laboratory from the turmoil of the directorship of the Office of Scientific Research and Development of a nation at war, where all that is potential in civilian science and technology has to be forged for a maximum of conflict power in a minimum of time and with a minimum of conflict in the forging, where the job to be done is only partially one of dealing with inanimate things and largely one of dealing with strong and frequently perverse men. I never cease to marvel at a man who in days filled with such turmoil can find the time and, above all, the philosophical detachment needed to formulate a state paper like the recent letter to Senator Kilgore on the problem of technological mobilization.

Even if time permitted, I am not competent to appraise and judge most of Doctor Bush's scientific contributions, except insofar as they can be judged by their end results. Rather, I find it pleasanter to deal with the man himself as I know him.

I first came to know Vannevar Bush at New London, Conn., during World War I, when, as a young man, he came to the antisubmarine laboratory. Even then I was struck with those characteristics which I was to find later were the hallmarks of the man—a brilliant versatile mind; an intense interest in and curiosity about everything that came within his ken; an uncanny ability to illuminate the dark corners of any matter to which he gave his attention; his fairness, simplicity and lack of ostentation; and, above all, his complete intellectual honesty.

While I know he wasn't born there, I always think of Bush as a Cape Codder. His roots are deep in the soil of that historic bit of sterile land on which our forefathers landed, and, metaphorically speaking, his shoes are full of its sand. Like thousands of others before him who have gone a pioneering on land and sea, he returns there periodically to replenish that sand and so insure keeping himself a realist in a too frequently unrealistic world.

Better than most men he can fight vigorously with any of the weapons men employ and do it without rancor. I have yet to see a case in which there was any aftermath of hard feeling or in which the feeling of respect and affection for him was not enhanced in the erstwhile antagonist.

In closing, I can only hope that I have not led you to think that he is a man who never makes mistakes. Even if I thought so I would scarcely dare make public proclamation of the fact, since I must protect my right to differ violently with him if occasion arises, as I know it will.

What I have sought to convey is the impression of a very able, very human man in whom are combined great ability, great energy, a great sense of reality, and the power of absolute truth, together with all the common qualities of men, including an ability to make mistakes. Unlike many men, he can and does admit error without losing face either with himself or anyone else; rather, he enhances it.

While I have no quarrel with the citation which accompanies the medal, and while I appreciate the limitations imposed by brevity in such matters, I cannot escape a feeling that the words chosen limit too narrowly the basis of his contributions which we seek to signalize. He is a great scientist and engineer, a great teacher and administrator, and a great American in a sense that no few words can encompass. To me that greatness is the greatness of many positive personal contributions and a host of others which his leadership has inspired.

In selecting Doctor Bush as the 1943 Edison Medalist the AIEE has shown great wisdom, and in making the award they have honored themselves as well as him.

The American Tradition of Opportunity

VANNEVAR BUSH, 1943 Edison Medalist

Thomas A. Edison exemplified an important aspect of American life. He combined, in superlative degree, resourcefulness and initiative with an intense practicality and a keen vision. The many results which he attained during his life sprouted from the blossoming of this combination of talent in an environment which was wonderfully adapted for such a growth.

I do not need to say to this audience that these are not the only characteristics that are needed in scientific and engineering endeavor. The list of Edison medalists is itself a demonstration of the recognition of the need for combining such qualities with scientific deduction, mathematical analysis, and the like, in order that there may be a rounded whole. Our great industrial advance, with its intense use of electric power and its intricate mechanization, has arisen by reason of the efforts of many types of mind. But without the important phase that Edison so notably exemplified the scene would indeed be a drab one.

The United States has prospered in a material way. It has attained a standard of living far beyond that arrived at in any other country. This is not entirely explained simply by the presence of great resources, or a large and uniform market, or even by the opportunities for pioneering that are summarized in the convenient term "the frontier." Neither does the opportunity for advancement necessarily vanish when the geographical frontier gives place to one that is entirely of a technical nature. The advancement has occurred because America brought a new idea into the world and because it was a valuable idea.

In a word, there was produced an atmosphere in which Edison could function, and in which men like him in having ideas and the intellect for their furtherance, however much they might differ from him as to method, could make their influence felt. The startling forward steps that Edison caused by his own efforts could not have occurred in a totalitarian state, whether the label were that of state

socialism or Fascism or something else. They could have occurred fully only under the unusual state of circumstances which obtained in this country when Edison worked and created. The atmosphere that existed is hard to define; it had its crudities, but it was a unique atmosphere and it is well worth preserving.

As the United States matures, we are in distinct danger of losing this enormous asset. The unwillingness to take risks which accompanies economic maturity, the cross-currents of pressure interests, the mere increase of interdependence due to the advance of mechanization, all tend to destroy the flexibility and freedom of action which are essential parts of the atmosphere of individual creation.

To the trends that were molding our environment and conditioning the atmosphere within which our pioneers worked was suddenly added the impact of war. We awoke late from a period of lethargy to find ourselves in an intense struggle caused by the clash of our political and social philosophies with ideologies far different from our own. When the war ends the readjustment will be difficult, and certainly we shall not return to the exact condition from which we departed when war came. We shall have learned many things, and it is to be hoped that we shall not forget them. It is of especial importance that, as we readapt ourselves to a new period of peace, we should preserve the essential features which made this country great. In particular, the opportunity for the individual creator, for the industrial pioneer, for the inventer with vision and practicality should not be lost; and the atmosphere of our industrial life should be favorable for his efforts in our behalf.

Vannevar Bush, 1943 Edison Medalist

We are now in a struggle with a capable and resourceful enemy in a highly technical modern war, and our enemy had a long head start. The effort to hold our own in a technical contest is not, and will not be, by any means a sinecure, or a struggle in which the outcome can be predicted a priori and with full confidence. We have had to mobilize our technical and scientific resources to the full, and we have had to do so with the confusion that is inevitable when a great lumbering democracy suddenly turns to war. It has been necessary to regulate, to impose controls, and to operate with a secrecy that is foreign to our usual open methods. It has not been necessary, however, to suppress thought and initiative and the democratic functioning of scientific and technical groups devoted to important phases of the technical aspects of the war effort. The results thus far have been good. We do not need to feel today that we are under a serious disadvantage because we started late, but we are still in an intense contest where every nerve must be stretched to attain important results, and we shall remain in this situation until the issue is decided.

Yet when the full tale is told, or the part of it is told which properly can be released, I am convinced that it will show one thing and that it will show this forcefully. The free untrammeled science and engineering of a democracy, when it once becomes directed toward an objective with full vigor, can outstrip the regimented efforts of any totalitarian state, provided there is anything approaching equality of resources on the two sides. I believe that it will come to be realized fully that our progress in manufacturing with enormous speed the weapons needed by our Armed Forces, in improving these weapons, in initiating new ones, and in keeping our civilian economy with its enormous technical complication still running effectively, has not been matched by the enemy, and that this has occurred in no small degree because our wartime effort was built upon the existing structure of freedom, with all that the word implies.

This must be preserved. As we turn again to the days of peace, it must be preserved in spite of the trends that flow from the greater interdependence of society, in spite of the trends that are inherent in the growing maturity of a nation, in spite of selfish interests of every sort. There must remain in the United States the opportunity for an Edison, the opportunity for any youth with initiative, resourcefulness, practicality, and vision, to create in his own name and by his own efforts new things that will tend to make this country vigorous and strong and safe.

The way in which this can be accomplished is not immediately apparent. The difficulty does not reside in the attitude of the people, for certainly there is an overwhelming majority that holds strongly to the conviction that freedom of individual opportunity must not be allowed to lapse, and that this involves genuine industrial opportunity for the individual, or the small group of individuals that join in a business effort. The difficulty arises from two facts. First, there are great sections of our industrial affairs that can be handled economically only by large industrial units. Second, the very complexity of modern life requires increased and centralized governmental activity, in order that the public interest may be fully protected and furthered by those measures of regulation and public works which government alone can perform adequately. The point is that, as a people, we have two parallel objectives; and we have been clumsy at times and allowed one to submerge the other.

In time of war concentration of effort and the imposition of rigid controls is essential for a fully co-ordinated all-out effort. The question is raised why, if this concentration is more effective for war, is it not also more effective for peace. One answer is the fact that the war concentration is effective primarily because it was constructed out of elements that became available and efficient under the relative freedom of peacetime conditions in a democracy, and there is no assurance that a brief effective concentration would remain so. Quite the contrary is what I believe the record of history will show. A more complete reply lies in the fact that we seek in the United States something beyond mere mechanical efficiency; we seek a society in which initiative and talent may have an outlet, and in which the individual may have opportunity

torise by his own efforts and contributions and not merely by the fixed operation of a system. We would be willing to sacrifice, if need be, some mechanical efficiency in the interests of individual freedom. My own conviction is that no sacrifice in the full effectiveness of the country is truly involved in the long run; and that, on the contrary, the elements which have rendered us strong in the past will render us still stronger in the future if we have sufficient intelligence and conviction to insist upon their preservation.

When peace returns, controls automatically will become relaxed. This is not enough. A negative slump back to a state of drifting, buffered by the trends that are inherent in technical progress, will not carry us on our appointed course as a nation. A positive and well-thought-out effort is needed if we are to combine the conditions of modern industry and modern government with that freedom within unitary organizations and within society as a whole which will allow the unusual individual to have a real chance of accomplishment and success. It can be done, if we have the steadfastness and conviction to insist that it be done. In this effort the great body of engineers and scientific men in the United States have an important part, for they are in a unique position to view and understand both sides of a matter which is primarily technical, economic, and organizational. If we are wise there will be, in the future, many Edisons in the United States. They may not shine with his peculiar brilliance, but they will add to the well-being of the nation a necessary element which can be added in no other way. Their opportunity must be preserved open before them.

Aircraft Transformers—Small and Light

O. KILTIE
ASSOCIATE AIEE

A three-phase 400-cycle 32-kva transformer measuring 5 by 9 by 12 inches and weighing 43 pounds is one example of the highly specialized types of transformers which have been designed to meet the needs of a-c applications on aircraft. Long life is deliberately sacrificed in order to gain small size and light weight, operating temperatures being as high as 225 degrees centigrade.

THE necessity for lightweight and small-size aircraft transformers is evident, since any reduction in space and weight will result in larger capacities for fuel and bomb loads. Various types of transformers have been developed recently, such as, three-phase to single-phase, single-phase to three-phase, two-phase to three-phase, three-phase to two-phase, combination a-c to d-c transformer–rectifier self-regulated units, miniature-instrument type, and a line of general-purpose aircraft units with kilovolt-ampere ratings ranging from 100 volt-amperes to 5 kilovolt-amperes, with weights ranging from 0.8 pound to 9.5 pounds and operating at ultimate temperatures of 225 degrees centigrade. Included are vibrator–inverter transformers, voltage stabilizers, and high-voltage and low-voltage booster ignition coils.

GENERAL FEATURES

The construction used on many of these designs features open core and coils and screw-type terminals. On those units intended for high-temperature operation the terminal boards are made of Mycalex, and all internal connections are joined with silver solder. For normal temperature design, cloth-base Textolite is employed in terminal-board construction.

In design, careful attention is given to locate the center of gravity as low as possible and as near the mounting surface as practicable. All units are also designed to withstand vibration tests specified by the United States Army and Navy.

Paper 43-146, presented at the AIEE national technical meeting, Salt Lake City, Utah, September 2-4, 1943, and published in AIEE *Transactions*, volume 62, 1943, pages 899–902.

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Core materials have been selected to operate at high flux density but not to saturate. Laminations ten mils thick, which provide for reasonable losses and allow practical manufacturing, are chosen for 400-cycle designs.

The choice of insulating materials is most important to permit operation of aircraft units at high temperatures far above those in past practices, furthering the primary object of weight reduction. All insulation in the special high-temperature units, including winding spools, layer insulation, wrappers, and conductor-turn insulation, is glass cloth and glass fiber impregnated with a specially developed resin capable of operating at 225 degrees centigrade.

To prevent oxidation of the copper wire at elevated temperatures the wire is cadmium plated prior to application of the glass fibers.

Overloads for short periods are permitted, during which the temperature may exceed operating values. This means that $1^1/_2$ to 2 times normal loads can be tolerated for a few minutes with no damage to the transformers.

Life tests have been completed on a four-pound two-kilovolt-ampere unit which operated in excess of 1,000 hours at 225 degrees centigrade. The unit was exposed to 95 per cent relative humidity, while cool and not operating, for eight hours in each 24-hour cycle. At the end of the life test the efficiency and heating had not changed appreciably, and continued operation was satisfactory.

ALTITUDE PERFORMANCE

Load tests have been made at sea level on a two-kilovolt-ampere 400-cycle high-temperature transformer to determine the extent of heating at various altitudes. To produce the same heating at other altitudes as obtained at sea

level, the load was then changed. The transformer is almost always mounted on a Dural plate or channel in the aircraft structure which will dissipate considerable heat. A comparison was made on transformer heating by making load test with the test unit mounted on a 12-inch-square Dural plate $^3/_{32}$-inch thick. The unit was then freely suspended in air to omit the plate. Heating data are shown in Table I.

Test data in Table II show that the core dissipates most

Table I. Heating Data for Various Altitudes With and Without Dural Plate

Altitude	Load in Watts	With Dural Mounting Plate	Ambient Temperature (Deg C)	Ultimate Temperature (Deg C) Outer Coil	Inner Coil	Top of Core
Sea level	2,000	Yes	30	172	208	172
Sea level	2,000	No	30	188	245	212
12,000 feet	2,000	Yes	30	181	217	186
12,000 feet	2,000	No	30	202	262	227
25,000 feet	2,000	Yes	30	193	229	199
25,000 feet	2,000	No	30	218	281	244
40,000 feet	2,000	Yes	30	206	242	208
40,000 feet	2,000	No	30	233	296	259

Table II. Output Loads at Various Altitudes for Same Core Temperatures

Altitude	Load in Watts	Ambient Temperature (Deg C)	Ultimate Temperature (Deg C) Outer Coil	Top of Core
Sea level	2,000	30	172	174
12,000 feet	1,830	30	156	174
25,000 feet	1,680	30	148	170
40,000 feet	1,570	30	144	170

Table III. Output Loads at Various Altitudes and Low Ambient Temperature

Altitude	Load in Watts	Ambient Temperature (Deg C)	Ultimate Temperature (Deg C) Outer Coil	Inner Coil	Top of Core
Sea level	2,000	−40	99	146	108
12,000 feet	2,000	−40	123	164	127
40,000 feet	2,000	−40	171	214	171

Table IV. Effects of Air Blast on Kilovolt-Ampere Rating at Various Altitudes

Altitude	Static Pressure Inches of Water	Load in Watts	Ultimate Temperature (Deg C) of Inner Coil
25,000 feet	0.27	2,000	117
40,000 feet	0.14	2,000	153
25,000 feet	0.27	2,670	212
40,000 feet	0.14	2,300	214

Table V. Electrical Data

Rating in Kilovolt-Amperes	Excitation Current in Per Cent of Full-Load Current	Voltage Regulation (Per Cent)	Efficiency (Per Cent)
0.100	42	13	87
0.250	35	11	90
0.500	26	10	91
1.000	10	7	92
2.000	7	6	93
5.000	6	5	94
32.500	5	4	95

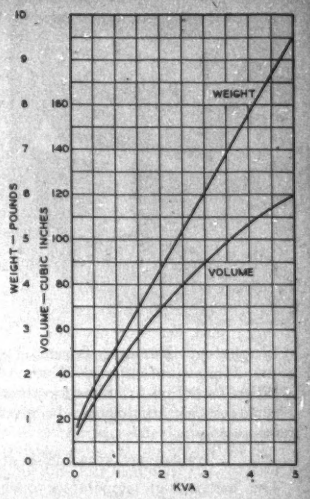

Figure 1. Weight and volume characteristic of high-temperature aircraft transformer.

of the total losses as indicated by constant core temperature and the reduction in coil temperature with reduced loads. It may be observed that for constant ambient temperature the allowable output at 40,000 feet is 79 per cent of normal sea-level capacity. However, since the lower ambient temperatures encountered at high altitudes will compensate for additional heating, it is safe to operate the transformer at full capacity at all times.

Test data given in Table III show comparative temperature rises of core and coils over an ambient temperature of minus 40 degrees centigrade. By comparing these data with the data from Table I (with Dural mounting plate) it may be observed that cold ambient temperatures are not so effective as warmer ambient temperatures on heat dissipation at the higher altitudes.

The effects of an air blast on heat dissipation are observed in Table IV. A velocity of air, measured to be 3,380 feet per minute, was forced over the unit for the purpose of obtaining

1. The decrease in heating at rated load of 2,000 watts.
2. The allowable increase in load to obtain the same heating as is encountered at sea level with no forced ventilation and with use of the Dural plate.

Regulation, efficiency, and exciting current data are given in Table V.

STANDARD LINE FOR GENERAL PURPOSES

A standard line of single-phase high-temperature lightweight transformers for general-purpose aircraft applications has been established. The kilovolt-ampere ratings are: 0.100, 0.250, 0.500, 1.000, 2.000, and 5.000. The voltage ratings are 120 volts high voltage and 28.5 volts low voltage. Frequencies of 380 cycles minimum to 420 cycles maximum are standard, although use of higher frequencies is not objectionable. An operating temperature rise of 200 degrees centigrade is normal and makes possible large reductions in size and weight when comparison is made with transformers constructed with conventional materials.

Figure 2. High-temperature aircraft transformer rated 400 cycles, 2.0 kva, 120 to 28.5 volts

Dimensions 2 3/8 by 4 1/4 by 4 3/8 inches

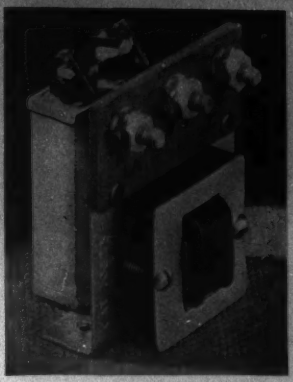

Figure 4. Single-phase to three-phase transformer rated 400 cycles, 48 volt-amperes, 115 volts single phase to 115 volts three phase

Dimensions 2 1/16 by 2 1/8 by 3 11/16 inches

Weights and volumes are shown in Figure 1. Construction and appearance may be observed from Figure 2.

When mounting locations for these transformers are selected, consideration should be given to the high temperature at which they operate.

THREE-PHASE TRANSFORMERS

The special high-temperature materials used in the single-phase units just described are also adaptable to the construction of three-phase 400-cycle units. For example, a 32-kva three-phase unit was made with dimensions of 5 by 9 by 12 inches and weighing only 43 pounds. A 7.5-kva three-phase unit was made with dimensions of 2 1/4 by 7 by 7 inches and weighing only 13 pounds. Three-phase units will weigh approximately 20 per cent more than single-phase units for the same kilovolt-ampere rating.

TRANSFORMER–RECTIFIER UNITS

Developmental work is well advanced on two self-regulated transformer–rectifier units to operate directly from an engine-driven a-c generator; these units are rated at 100 and 200 amperes, respectively, at 30 volts, d-c output. The input frequency and voltage may vary independently of each other. The d-c output voltage may be selected at any value between 26 and 30 volts and held constant, regardless of load-current variations from no load to full load. The circuit includes a control reactor, a three-phase high-temperature transformer, a voltage-sensitive variable resistor, and a selenium rectifier. Units rated at 3.0 kw and 6.0 kw will weigh approximately 30 pounds and 55 pounds, respectively.

PHASE-CHANGING TRANSFORMERS

A definite trend toward increased use of single-phase electric equipment on aircraft has been noted. Many planes, particularly large bombers, have, as standard equipment, three-phase auxiliary generators, which, of course, are of limited capacity. A single-phase load connected to any one phase of the power supply would cause considerable unbalance in the three-phase voltages, which would also reduce the available volt-ampere capacity of the generator. Therefore, it became desirable to develop a transformer to furnish a single-phase voltage which could reflect balanced watts at equal power factors in the three generator phases. Several designs have been completed in various ratings. Their efficiency is 90 per cent, and they operate at unity input power factor. Load variations do reflect in some unbalanced input power factor, but the output voltage regulation is not seriously affected. It is essential that phase rotation always be maintained in the stipulated direction and that the frequency remain constant. One such unit has been produced which will deliver 115 watts at 115 volts and 400 cycles from a three-phase 1,000-volt-ampere generator for the operation of a single-phase radio compass of an automatic pilot. This unit weighs 2.38 pounds and has dimensions of 2 1/8 by 3 7/8 by 5 1/2 inches. Refer to Figure 3 for a construction view.

For operation of small gyro instruments three-phase motors have been found most suitable. This makes it necessary on such aircraft as fighters, which are equipped with single-phase generators, to use single-phase to three-phase transformers for operation of these instruments. A transformer using a special nonlinear split-phase circuit is now available which will supply 115 volts, three-phase, at 400 cycles from a 115-volt single-phase generator supply. This supply will operate two *KB-1* or *KC-1* General Electric gyro instruments having a total load of 48 volt-

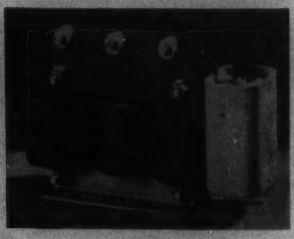

Figure 3. Three-phase to single-phase aircraft transformer rated 400 cycles, 0.115 kva, 115 volts three phase to 115 volts single phase

Dimensions 2 by 3 1/8 by 5 1/4 inches

Figure 5. Instrument autotransformer rated 400 cycles, 9.0 volt-amperes, 120 to 28.5 volts

Dimensions 1 3/8 by 1 3/8 by 1 3/4 inches

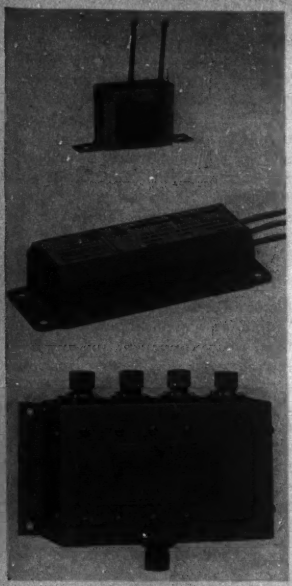

Figure 6. Reactor ballasts for fluorescent lighting on aircraft

minute in physical size. Refer to Figure 5 for construction view.

Small linear a-c reactors, required for certain miniature instruments, have also been developed. One such unit, rated 74 volts, 0.03 ampere, 400 cycles, and designed for assembly within the instrument, has a volume of only $1\frac{1}{4}$ cubic inches and weighs but two ounces.

Reactor ballasts are available for fluorescent lighting in aircraft having a suitable a-c power system. They serve the same purpose as in commercial practice, except that they are designed for light weight and small size and 400 cycles. Refer to Figure 6 for typical units.

VOLTAGE-STABILIZER TRANSFORMER

A recent development in voltage stabilizer for 60-cycle service is equally adaptable for 400-cycle or even 800-cycle aircraft systems. These units are used for those instruments which require a constant regulated input voltage. If the frequency is constant, the load, power factor, and input voltage may vary over wide limits; if the load and its power factor are constant, the input line voltage may vary; the frequency may also vary over a ten per cent range and yet provide for a constant output voltage held to within approximately three per cent.

Figure 7A (left). Low-voltage ignition booster coil

Figure 7B (right). High-voltage ignition booster coil

amperes. This transformer is so designed that it compensates for the difference in starting and operating load power factors and thus permits rapid acceleration of the gyro motors; however in general, this type of transformer should be designed for specific loads in which the power factor and volt-amperes are essentially constant. The transformer is both small and lightweight, weighing only eight ounces. Refer to Figure 4 for a construction view.

There are other aircraft applications that require the use of two-phase to three-phase or three-phase to two-phase transformers. Such units can be made small and lightweight by use of special steels and insulating materials.

TRANSFORMERS FOR OTHER AIRCRAFT APPLICATIONS

Small single-phase transformers of 4.5- and 9.0-watt ratings are available for operation of other flight instruments such as the remote indicating compass. These units weigh only two and three ounces, respectively, and are

Figure 8. Vibrator-type inverter–transformer rated 24 volts direct current to 16-16 volts alternating current at 60 cycles with radio interference suppressed

BOOSTER IGNITION COILS

In the past it was common practice to use high-voltage ignition booster coils for providing positive ignition in starting aircraft engines. Recently, low-voltage booster coils have been made available, which operate directly from the battery and furnish rated current through the low-voltage winding of the magneto.

This low-voltage current is then stepped up by transformer action within the magneto to provide a high-voltage output suitable for ignition starting purposes. This system is being used extensively and is more practical in that it simplifies wiring and reduces radio interference. Refer to Figures 7A and B for typical units.

INVERTER TRANSFORMERS

Inverter transformers are available for those applications requiring a conversion of power from direct to alternating current or requiring a d-c voltage change. The frequency of the vibrator, which is an essential part of the equipment, is limited to a preferred 120 cycles. This prevents the adoption of inverter transformers, generally, to 400-cycle systems. They are now used extensively to provide a-c voltage to a special field winding of power-turret Amplidyne generators for controlling voltage fluctuations caused by residual flux. Without such control the turret will become unstable, and thus its accuracy will be reduced. A small two-pound inverter transformer operating directly from the battery will provide the necessary control. Refer to Figure 8 for a typical unit.

Inverters can be made to operate directly from the variable battery voltage to provide a self-regulated a-c or d-c output voltage held constant within approximately three per cent. Wave form is almost equivalent to sine wave and entirely suitable for most applications.

A circuit[1] is usually employed in which the vibrator contacts do not break current. This provides for long reliable life of the equipment. Improvements have been made recently to correct the output wave form, increase the efficiency, and provide stabilized output voltage.

CONCLUSIONS

The transformers discussed in this article are those which seem most needed for aircraft applications. In many cases they have replaced heavy equipment and also have made it possible for certain generators to serve dual purposes.

There may be many other applications which have not been mentioned; however, it is hoped that the information disclosed herein may be of value in solving transformer problems in the aircraft industry.

REFERENCE

1. New Type of D-C to A-C Vibrator Inverter, O. Kiltie. AIEE *Transactions*, volume 59, 1940, April section, pages 245–7.

Official United States Navy photo

United States dive bomber over Wake Island

A Simple Method for Locating Ground Faults

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MEMBER AIEE

This article presents a simple, convenient, and inexpensive plan for determining the approximate location of ground faults on long transmission lines. Methods in use for locating all types of transmission-line faults are discussed briefly, but the main object is a discussion of line-to-ground faults, which occur far more frequently than phase-to-phase faults.

WHEN A FAULT occurs on a long transmission line it is highly desirable to be able to determine quickly the location of the fault so that valuable time may be saved in restoring the line to service. Use is made of various devices for this purpose.

Directional Distance Relays. For a tie line protected with directional distance relays of the three-zone type, some idea of the approximate location of a phase-to-phase fault can be obtained by observing the relay targets at the two ends of the faulted line. For example, if the first-zone targets operate at station *A* and the second-zone targets operate at station *B*, it is logical to assume that the fault is located in the end zone near station *A;* that is, somewhere within the ten per cent of the line length nearest station *A*. On the other hand, should the first-zone targets operate at station *B* and the second zone targets at station *A*, one would conclude that the fault is in the end zone nearest station *B*. If the first-zone targets operate at both ends of the line, it is evident that the short circuit is located within the 80 per cent of the line length between the two end zones. In other words, in this latter case, for a 100-mile line the short circuit would be at least ten miles out from either station, and as much as 80 miles of line might have to be patrolled between the two end zones.

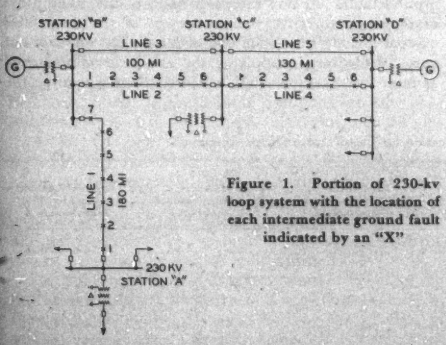

Figure 1. Portion of 230-kv loop system with the location of each intermediate ground fault indicated by an "X"

Automatic Oscillographs. From the foregoing discussion it can be seen that while the distance relay targets do not furnish much information as to the location of a line fault, they do give some indication that is helpful to the trouble shooters. To get a closer approximation of the fault locations it would be necessary to install an automatic oscillograph at each end of a line to operate only during fault conditions. The oscillographs could be connected to record the bus voltages and the current in the three phases. However, it should be remembered that automatic oscillographs are rather expensive and, also, are hard to get under present war conditions.

High-Speed Graphic Meters. High-speed graphic meters are used to advantage on power systems with relatively slow relaying. For such a meter the pen pressure must be adjusted carefully to prevent bouncing when the meter goes into high speed, and the pen and inkwell must be cleaned at frequent regular intervals. This type of meter is too slow for a power system with fast relaying.

Electronic Devices. According to the March 1943 issue of *Electronics*,[1] some power systems now use carrier remote control to aid in locating quickly the faulty section of line when line failure occurs. This method requires the construction of carrier-controlled switching stations along the lines. Switching is thereby speeded up, as it becomes only a matter of dialing a number from the supervisory desk to open or close a remote switch. In this way, it is possible to determine quickly the approximate location of the line fault and to drop out that section of line.

Another electronics application for locating line faults is the use of a new device consisting essentially of a variable-frequency oscillator which feeds radio-frequency power into the line under test. The current fed into the transmission line is measured by a meter in the oscillator circuit.[1]

Disturbance Recorders. A disturbance recorder has been developed by Lloyd F. Hunt of the Southern California Edison Company and is described in the AIEE *Transactions*.[2] In some respects it is similar in operation to high-speed graphic meters on the market except that the pen is replaced with a spark gap.

Annunciator-Type Ammeters. Simple inexpensive annunciator-type ammeters can be applied with reasonable satisfaction for registering the magnitudes of fault currents. This type of ammeter consists of a number of target coils wound to operate in various current steps. Ammeters with six target coils are used on the Bonneville Power Administration system. The current value is printed on each target so that an operation will bring the printed

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Table I. Line-Fault Data for Line 1

Fault Location in Miles from Station A	Maximum Ground Current in Amperes: From Station A		From Station B		Total Ground Current	From Station A With Line Open at B		From Station B With Line Open at A		Station to Clear First
	Primary	Secondary*	Primary	Secondary*		Primary	Secondary*	Primary	Secondary*	
Near station *A*	3,040	30.4	260	2.6	3,300	2,780	27.8	490	4.9	*A*
30	1,620	16.2	465	4.6	2,085	1,505	15.0	565	5.6	Simultaneous
60	1,075	10.7	640	6.4	1,715	1,055	10.5	690	6.9	Simultaneous
90	815	8.1	865	8.6	1,680	805	8.0	890	8.9	Simultaneous
120	605	6.0	1,205	12.0	1,810	640	6.4	1,195	11.9	Simultaneous
150	450	4.5	1,930	19.3	2,380	525	5.2	1,925	19.2	Simultaneous
Near station *B*	175	1.7	4,895	48.9	5,070	450	4.5	4,520	45.2	*B*

* Assumed current-transformer ratio of 500 to 5 amperes.

figure into view. Calibration of the targets may be in terms of either primary or secondary amperes. For purposes of this article we shall consider an annunciator-type ammeter with targets calibrated for 1, 3, 5, 10, 15, and 20 secondary amperes for the two ends of line 1 in Figure 1. If targets 1, 3, and 5 are up, it is known that the secondary current is more than five amperes but less than ten amperes. Similarly, if five of the six targets are up, the current is between 15 and 20 secondary amperes.

APPLICATION OF ANNUNCIATOR-TYPE AMMETER FOR LOCATING GROUND FAULTS

First of all, a ground-fault study must be made of the line under consideration. For example, let us consider a simple case; that of a 180-mile 230-kv transmission line connecting two stations *A* and *B* and labeled as line 1 in Figure 1. Fault currents are determined for intermediate points on the line in addition to those for the two ends by the use of a short-circuit calculating board. In this case, a ground fault is considered at each end of the line and also at five intermediate points. The current flow to the ground fault must be calculated with both ends of the line closed and also with one end open. These fault currents, shown in Table I, were determined on the calculating board by members of the Bonneville staff.

LOCATION OF FAULTS ON LINE 1

Table I shows the location of the fault, the total ground current and the input from each end before either end of the line clears by relay, the input to the fault from station *B* with the breaker open at station *A*, and the current flow from station *A* to the fault with the line open at station *B*. An examination of the table shows that, for this particular case, after one end of the faulty line opens, the current flow from the opposite end increases. This must be taken into account in analyzing the meter readings following the clearing of a ground fault. All fault-current values are maximum rms values, as no allowance has been made for any resistance at the point of fault. Secondary currents have been calculated on the basis of 500/5-ampere current transformers. In addition to directional distance relays, each end of the line is protected with a directional time-delay overcurrent ground relay and an instantaneous nondirectional overcurrent ground relay.

Table II shows a method for determining approximate fault ground currents. One might conclude that actual fault currents in all cases will be much smaller than the calculated values, because of contact resistance at the point of fault, but staged tests on a 230-kv circuit on the Bonneville system do not confirm this conclusion. It was found that the measured values of fault current were only four to five per cent smaller than our calculated values. Of course, on lower-voltage circuits, the fault resistance does have an appreciable effect on the magnitude of a ground fault. At any rate, regardless of the magnitudes of the fault currents, the percentage of the total fault current flowing from each end of the faulted line will not vary. However, in applying the annunciator ammeters as fault locators, it should be noted that, whenever the

Table II. Determination of Line-Fault Location by Use of Annunciator Ammeters

Ammeter at Station A: Highest Target	Ammeter at Station A: Primary Amperes	Ammeter at Station B: Highest Target	Ammeter at Station B: Primary Amperes	Total* Calculated Ground Fault Current (Amperes)	Per Cent of Total From Station A (Calculated)	Per Cent of Total From Station B (Calculated)	Apparent Location of Fault in Miles From Section A
20	Above 2,000	3	Above 300 Below 500	3,300	92	8	Near station *A*
15	Above 1,500 Below 2,000	3(5?)	Above 300 Below 500	2,085–3,300	78–92	8–22	Up to 30
10	Above 1,000 Below 1,500	5	Above 500 Below 1,000	1,715–2,085	63–78	22–37	30 to 60
5	Above 500 Below 1,000	5	Above 500 Below 1,000	1,680–1,715	48–63	37–52	60 to 90
5	Above 500 Below 1,000	10	Above 500 Below 1,000	1,680–1,810	33–48	52–67	90 to 120
3 (5?)	Above 300 Below 500	15	Above 1,500 Below 2,000	1,810–2,380	19–33	68–81	120 to 150
3	Above 300 Below 500	20	Above 2,000	2,380–5,070	2–19	81–98	150 to 180
3	Above 300 Below 500	20	Above 2,000	5,070	2	98	180

* Ground current before any breakers open.

Ammeters show maximum residual current flow from each end of line from instant that fault occurs until it is cleared. Assume current transformer ratio of 500 to 5 amperes at each end of line.

secondary ground current is just a trifle above the rating of a certain ammeter target, it is questionable whether that target will operate, and due allowance must be made for that fact.

As an example, for a ground fault at mile 30, the calculations show a flow of 1,620 amperes from station *A* and 465 amperes from station *B*. The secondary current at station *B* is equivalent to 4.6 amperes. The instantaneous ground relay at station *A* can be set to operate as low as 2.5 amperes and the one at station *B* as low as four amperes without operating for a bus fault at the opposite end of the line. However, the resistance in the fault itself can decrease the relay current from station *B* below four amperes and prevent it from operating. Then station *A* will clear first. If the resistance of the fault itself is ignored, the secondary relay current at *B* will increase to 5.6 amperes after station *A* clears. In this case the highest target may be either the three-ampere target or the five-ampere target. In all probability, only the one- and three-ampere targets will show at station *B* after the line fault is cleared at both ends.

With similar instantaneous ground relays and similar breakers at the two ends of the line, it is expected that both ends of the line will clear simultaneously for low-resistance ground faults anywhere between mile 30 and mile 150. However, any slight difference in time delay between relay and breaker at one end of the line as compared to the relay and breaker at the other end will cause one end to open first and to change the flow of ground current. The ammeter targets, however, will be affected by this change in current only for faults at the two end zones of the line, as indicated in Table I.

The per cent of total fault current from each end of the line at the instant a fault occurs is shown graphically in Figure 3, while Figures 4 and 5 show the changes in ground current after a breaker opens. For these calculations transient-reactance values have been used for all generators and synchronous machines.

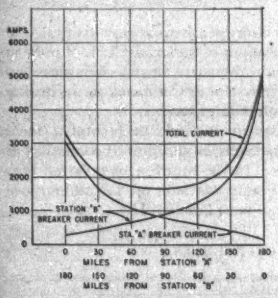


Figure 2. Ground currents for single phase - to - ground faults on line from station A to station B

Load: Three 230-kv generators on station B. Currents are plotted to show the total maximum current flow to a ground fault at any intermediate point on line 1, and also the magnitude of the current flowing from each end of the line

PARALLEL LINES 2, 3, 4, AND 5

Similar fault-current readings have been made for lines 2 and 3 between stations *B* and *C*, and for lines 4 and 5 between stations *C* and *D*. These data are shown in Tables 3 and 4. In these cases, because of the effect of mutual induction between the parallel lines, the application becomes more difficult.

Table III. Line-Fault Data for Line 2

Fault Location in Miles From Station B	Maximum Ground Current in Amperes: From Station B		From Station C		From Station B With Line Open at C		From Station C With Line Open at B	
	Primary	Secondary*	Primary	Secondary*	Primary	Secondary*	Primary	Secondary*
Near station *B*	5,225	52.2	160	1.6	5,235	52.3	855	8.5
20	2,500	25.0	585	5.8	2,580	25.8	980	9.8
40	1,565	15.6	855	8.5	1,775	17.7	1,150	11.5
60	1,100	11.0	1,150	11.5	1,385	13.8	1,385	13.8
80	765	7.6	1,590	15.9	1,100	11.0	1,785	17.8
Near station *C*	480	4.8	2,380	23.8	930	9.3	2,495	24.9

* Assumed current transformer ratio of 500 to 5 amperes.

Table IV. Line-Fault Data for Line 4

Fault Location in Miles From Station C	Maximum Ground Current in Amperes: From Station C		From Station D		From Station C With Line Open at D		From Station D With Line Open at C	
	Primary	Secondary*	Primary	Secondary*	Primary	Secondary*	Primary	Secondary*
Near station *B*	2,315	23.1	350	3.5	2,440	24.4	675	6.7
27	1,400	14.0	570	5.7	1,550	15.5	800	8.0
54	945	9.4	830	8.3	1,130	11.3	1,000	10.0
81	680	6.8	1,200	12.0	900	9.0	1,320	13.2
108	465	4.6	1,970	19.7	750	7.5	2,010	20.1
Near station *D*	110	1.1	4,305	43.0	650	6.5	4,190	41.9

* Assumed current transformer ratio of 500 to 5 amperes.

Incidentally, the parallel lines under discussion are protected with time-delay directional ground relays, non-directional instantaneous ground relays, and high-speed current-balance ground relays. Both ends of a faulty line will clear almost simultaneously except for ground faults in the two end zones.

It will be noted that for a ground fault on line 2 near station *C*, the flow of ground current over the line from station *B* increases from 480 amperes to 930 amperes after the line opens at *B*. For line 4 the effect is even more pronounced, because, when the breaker at station *D* opens for a ground fault at that end of the line, the flow of ground current over the line from station *C* increases from a mere 110 to 650 amperes.

It is apparent that for lines 2 and 3 it would be advisable to install ammeter targets of a somewhat higher current range than for line 1. For example, for lines 2 and 3 at station *B* the targets could be wound for 3, 5, 10, 20, 30, and 40 secondary amperes. The targets for the other end of these two lines could be wound for 1, 3, 5, 10, 15, and 20 amperes. Space does not permit going into detail regarding the operation of the targets for the parallel lines but the application is somewhat similar to that outlined for line 1.

LOCATION OF ANNUNCIATOR AMMETERS

It has been assumed in this discussion that the annunciator ammeters are installed in the residual circuit of the line current transformers, but they can be installed also in the grounded neutral circuits of the power transformers at the stations. It would then be necessary to determine the per cent of the total ground current contributed by each bank for the various line faults.

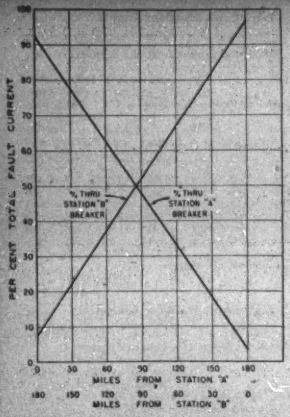


Figure 3. Per cent of total current from each end of the line for single phase-to-ground faults, and for intermediate points along the line

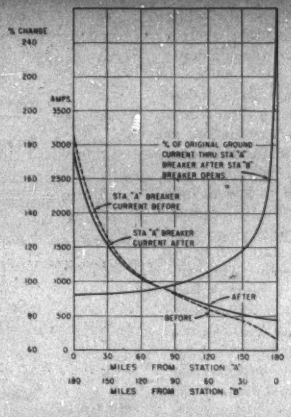

% CHANGE
AMPS.
% OF ORIGINAL GROUND CURRENT THRU STA "A" BREAKER AFTER STA "B" BREAKER OPENS
STA "A" BREAKER CURRENT BEFORE
STA "A" BREAKER CURRENT AFTER
AFTER
BEFORE
MILES FROM STATION "A"
MILES FROM STATION "B"

Figure 4. Change of current through station A line breaker after station B breaker opens, for single phase-to-ground faults

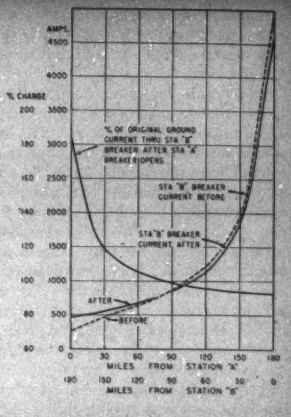

% CHANGE
AMPS.
% OF ORIGINAL GROUND CURRENT THRU STA "B" BREAKER AFTER STA "A" BREAKER OPENS
STA "B" BREAKER CURRENT BEFORE
STA "B" BREAKER CURRENT AFTER
AFTER
BEFORE
MILES FROM STATION "A"
MILES FROM STATION "B"

Figure 5. Change of current through station B line breaker after station A breaker opens, for single phase-to-ground faults

OPERATING EXPERIENCE WITH ANNUNCIATOR AMMETERS

Fault calculations have been made for the power system of the Bonneville Power Administration, involving ground faults at intermediate points on the longer 230-kv lines for the purpose of applying annunciator-type ammeters to determine quickly the location of a line-to-ground fault after a tripout. The operating personnel reports very gratifying results. In fact, in one case they predicted the location of the fault within a mile or two.

CONCLUSIONS

When a fault occurs on a transmission line it is important to isolate, locate, and repair the fault quickly in order to keep service interruptions to a minimum. During present conditions it is more important than ever to keep the power flowing so that reductions in the output of war equipment can be prevented.

The shortage of man power and strategic war materials makes it necessary for the power systems to carry the added war loads with a minimum of new equipment, including all types of switchboard equipment. For these reasons use should be made of the simplest device which will do a given job with a reasonable degree of satisfaction.

In this article the discussion has centered around such an instrument—the annunciator ammeter. It is not the ideal device for helping to determine the location of ground faults, but it is inexpensive and easy to install and requires a minimum amount of material. It is of interest to note that annunciator ammeters also are being used to some extent on a power system in California for recording the magnitudes of ground fault currents.

For a large power system it would be helpful to have several portable oscillographs in addition to a number of annunciator ammeters. In the future, it is believed that electronics devices will be in common use for the purpose of determining the location of line faults.

REFERENCES

1. Power Company Uses of Electronic Equipment, **W. H. Blankmeyer**, *Electronics*, volume 16, March 1943, pages 134–5; 169–74.

2. Locating Grounds by Distribution Ratio Method, **W. F. Dunkle** and **J. S. De Shazo**, *Electrical Engineering*, volume 53, March 1934, pages 258–61.

3. Some Practical Measuring Devices, **Lloyd F. Hunt**. AIEE *Transactions*, volume 59, 1940, pages 765–8.

INSTITUTE ACTIVITIES

North Eastern District Technical Meeting to Be Held in Boston, Mass., April 19–20

A two-day technical meeting of the AIEE North Eastern District will be held in Boston, Mass., Wednesday, April 19, and Thursday, April 20, 1944. Meeting headquarters will be at the Hotel Statler. The committees have arranged a broad program, which has been planned to help engineers engaged in promoting the war effort. Seven technical sessions will be held on the subjects of cables, transformers and selected subjects, electronics, power transmission, air transportation, electrical machinery, and industrial power applications. In addition, a student technical session will be held, at which papers will be presented by the students.

The 60th anniversary of the AIEE will be observed by a special session on Wednesday afternoon. In this session there will

Tentative Technical Program and Features

Tuesday, April 18

Afternoon Registration

8:00 p.m. Technical-Paper Competition for Younger Engineers

Hotel Statler, Salle Moderne. **R. W. Adams,** presiding Tri-Sectional prize competition, sponsored by Schenectady, Lynn, and Pittsfield Sections

Wednesday, April 19

9:00 a.m. Registration

10:00 a.m. Cables

E. W. Davis, presiding

HIGH-FREQUENCY CABLE DESIGN AND TESTING. **N. D. Kenney, P. W. Ware,** Simplex Wire and Cable Company

44-53. CURRENT RATING OF CABLES AS AFFECTED BY MUTUAL HEATING IN AIR OR CONDUIT. Insulated Power Cable Engineers Association committee on research

ADDITIONAL EXPERIENCE WITH GAS-FILLED CABLES. **G. B. Shanklin,** General Electric Company

SYNTHETIC INSULATION FOR CABLES. **C. A. Finkel,** The Okonite Company

FIELD TESTING AND FAULT LOCATION IN CABLES. **W. D. Fenn, L. A. Gray,** Simplex Wire and Cable Company

10:00 a.m. Transformers and Selected Subjects

C. T. Burke, presiding

IMPULSE TESTING OF TRANSFORMERS. **J. H. Hagenguth,** General Electric Company

DESIGN OF VARIAC TRANSFORMERS. **Edward Karplus,** General Radio Company

RELIABILITY OF COMPRESSED-GAS INSULATION. **J. D. Cobine, E. C. Easton,** Harvard University

AIR-COOLED DRY-TYPE REGULATORS. **L. G. Tubbs,** Westinghouse Electric and Manufacturing Company

APPLICATION AND DESCRIPTION OF AUTOMATIC CONTROL AND SWITCHING EQUIPMENT FOR CAPACITOR BANKS. **T. W. Schroeder, W. C. Bloomquist,** General Electric Company

SMALLER-TANK OIL CIRCUIT BREAKERS. **W. M. Leeds,** Westinghouse Electric and Manufacturing Company

10:00 a.m. Student Session

G. Minalga, presiding

Four student papers to be presented. Titles and authors to be announced later.

2:00 p.m. AIEE 60th Anniversary Observance

1. HISTORY OF THE INSTITUTE
2. FUTURE OF ELECTRICAL ENGINEERING AND THE INSTITUTE
3. THE FUTURE OF AERONAUTICS

• PAMPHLET reproductions of authors' manuscripts of some of the papers listed in the program may be made available. Abstracts of these papers will appear in the April issue.

• PRICES and instructions for procuring advance copies will accompany the abstracts.

6:00 p.m. Presidential Reception

6:30 p.m. Get-Together Dinner

Statler Hotel Imperial Ballroom. **William H. Timbie,** toastmaster

Presentation of District prizes for papers

Nationally known speaker to be announced

Thursday, April 20

9:30 a.m. Electronics

T. S. Gray, presiding

DEVELOPMENT OF EXCITRON-TYPE RECTIFIER. **H. Winograd,** Allis-Chalmers Manufacturing Company

IGNITRONS, THEIR DEVELOPMENT AND USES. **J. C. Cox,** Westinghouse Electric and Manufacturing Company

OPERATION OF RECTIFIERS UNDER UNBALANCED CONDITIONS. **M. M. Morack,** General Electric Company

A GRAPHICAL ANALYSIS OF THE VOLTAGE AND CURRENT WAVE FORMS OF CONTROLLED-RECTIFIER CIRCUITS. **P. T. Chin, E. E. Moyer,** General Electric Company

ELECTRONIC CONTROL FOR D-C MOTORS. **B. J. Dalton,** General Electric Company

BROAD-BAND CARRIER SYSTEM FOR TELEPHONE CABLES. **J. P. Thurber,** New England Telephone and Telegraph Company

9:30 a.m. Power Transmission

C. A. Corney, presiding

110-KV TIE-LINE USES PROGRESSIVE DESIGN. **E. A. Church, E. G. Stebbins,** Boston Edison Company

IMPROVING THE PERFORMANCE OF 110-KV TRANSMISSION CIRCUITS. **D. H. Hathaway, A. B. Jones,** Boston Edison Company

CONVERSION OF MONTAUP ELECTRIC SYSTEM FROM 66-KV TO 110-KV. **W. B. Carnie,** Montaup Electric Company

MEASURED ELECTRICAL CONSTANTS 270-MILE 154-KV LINE. **C. A. Streifus,** Ebasco Service, Inc.; **C. S. Roadhouse,** Nebraska Power Company; **R. B. Gow,** Kansas Gas and Electric Company

2:00 p.m. Air Transportation

R. W. Adams, presiding

A-C AND D-C SHORT-CIRCUIT TESTS ON AIRCRAFT CABLES. **J. C. Cunningham, W. M. Davidson,** Westinghouse Electric and Manufacturing Company

ELECTRICALLY DRIVEN GYROSCOPES FOR AIRCRAFT. **H. M. Witherow, Albert Hansen, Jr.,** General Electric Company

DAMPING CYLINDERS FOR AIRCRAFT GYROSCOPES. **F. R. Sias, J. H. Wright,** General Electric Company

A UNIT FOR BALANCING THE VOLTAGES OF THREE-PHASE AIRCRAFT INVERTERS SUPPLYING LARGE SINGLE-PHASE LOADS. **Sydney Wimpiss,** The Holtzer-Cabot Electric Company

BLAST-TUBE COOLING FOR AIRCRAFT GENERATORS. **C. G. Veinott,** Westinghouse Electric and Manufacturing Company

AIDS TO QUALITY CONTROL IN THE MANUFACTURE OF AIRCRAFT GENERATORS. **F. M. Potter,** General Electric Company

DIFFERENTIAL GENERATOR CONTROL RELAYS FOR D-C AIRCRAFT ELECTRICAL SYSTEMS. **F. E. Crever,** General Electric Company

2:00 p.m. Electrical Machinery

H. B. Ashenden, presiding

PREVENTION OF ROTOR-WINDING DEFORMATION ON TURBOGENERATORS. **J. G. Noest,** Consolidated Edison Company of New York, Inc.

VIBRATION PROTECTION FOR ROTATING MACHINERY. **R. L. Webb, C. S. Murray,** Consolidated Edison Company of New York, Inc.

EXCITERS FOR 3,600-RPM GENERATORS. **Clarence Lynn,** Westinghouse Electric and Manufacturing Company

BEHAVIOR FACTORS OF RECTIFIER-DRIVEN D-C MOTORS. **Victor Siegfried,** Worcester Polytechnic Institute

INTERPRETATIONS OF CURRENT-TIME CURVES AS APPLIED TO INSULATION TESTING. **R. F. Field,** General Radio Company

2:00 p.m. Industrial Power Applications

F. S. Bacon, Jr., presiding

VOLTAGE REGULATION IN INDUSTRIAL PLANTS. **Hugh McCrea,** General Electric Company

CAPACITORS IN INDUSTRIAL PLANTS. **J. E. Barkle,** Westinghouse Electric and Manufacturing Company

POWER SUPPLY FOR RESISTANCE WELDERS. **R. L. Briggs,** Thomson-Gibb Electric Welding Company

ELECTRONIC CONTROL FOR VARIABLE-SPEED MOTORS. **W. I. Bonds,** Westinghouse Electric and Manufacturing Company

SPEED CONTROL OF A-C MOTORS. **F. B. Hacussler,** General Electric Company

MAINTENANCE OF INDUSTRIAL MOTORS AND CONTROL. **H. E. Thomas,** Westinghouse Electric and Manufacturing Company

ELECTRONIC HEATING. **H. M. Chatto,** General Electric Company

This shell on the Esplanade along the Charles River just above Longfellow Bridge is the scene of outdoor concerts in Boston, Mass., in which city the North Eastern District technical meeting will be held April 19–20, 1944

be addresses on the history of the Institute, the future of electrical engineering and the Institute, and the future of aeronautics. On Wednesday evening a presidential reception will be followed by a get-together dinner. W. H. Timbie, Massachusetts Institute of Technology, Cambridge, will act as toastmaster, and the meeting will be addressed by a prominent speaker.

REGISTRATION

Members of the District and others who receive a mailed announcement of the meeting should fill in and return registration cards immediately upon receipt. Members from neighboring AIEE Districts will be most welcome. A registration fee of two dollars will be charged all nonmembers except Enrolled Students and the immediate families of members.

COMMITTEE

The general committee making the arrangements is headed by the following:

T. Cooper, Jr., *general chairman;* R. G. Porter, *vice-chairman;* J. M. Murray, *secretary–treasurer;* C. L. Dawes, *chairman, technical program;* J. G. Patterson, *secretary, technical program;* D. C. Jackson, *60th anniversary;* A. L. O'Banion, *hotel and registration;* F. S. Bacon, *dinner;* R. G. Porter, *student activities;* F. W. Bliss, *publicity.*

Well-Rounded Winter Meeting Best Attended Since 1941

Boasting a total registration of 1,658 members and guests, the 1944 AIEE winter technical meeting, held January 24–28 in New York, N. Y., was the best attended since the 1941 winter meeting held in Philadelphia, Pa., when 1,931 were registered. The absence of bad weather during the meeting—for the first time in several years—may have been a cause of the increased registration. All technical sessions and conferences of the well-rounded program were exceptionally well attended, in many instances taxing the capacity of the meeting rooms in the Engineering Societies Building. As in previous wartime meetings, first attention was devoted to problems related either directly or indirectly to the war effort.

The final meeting program deviated from the tentative program published in the January issue in several respects. There were no conferences on welding, marine transportation, or automatic stations. The special lecture and inspection trip at the Brooklyn Navy Yard for specially selected and invited teaching personnel scheduled for Saturday morning was divided into two parts: the lecture, on "Power Aspects of the Electric Circuit and Electric-Machinery Courses in the Navy V-12 Program," which was given Friday morning at the Engineering Societies Building; and the inspection trip through the Navy Yard which was taken Thursday afternoon.

Among important official actions taken at the meeting was the authorization by the AIEE board of directors of a committee to study conditions affecting the security of employment and compensation among electrical engineers, with special reference to the problem of collective bargaining. Details are given in a separate item.

TECHNICAL SESSIONS AND CONFERENCES

Topping the list of technical sessions and conferences related directly to the war were two sessions on electrical applications to air transportation and two conferences devoted to a discussion of problems associated with the military specialized training programs. One conference was devoted primarily to electrical problems of war industries. In addition, many of the papers presented at the sessions on power generation, transmission and distribution, electrical machinery, protective devices, electrical measurements, land transportation, and communication, were related to problems imposed by wartime conditions.

Brief reports of the conferences are given in succeeding pages. With the exception of the few instances where session chairmen furnished accounts of the technical sessions, however, the sessions are not reported here, as all approved papers and discussions will be published in the *Transactions*.

GENERAL SESSION

A departure from the custom of presenting the Edison Medal at an evening session, the presentation ceremonies this year took place during the first half of the general session Wednesday morning, January 26. As previously announced, the medal was presented to Vannevar Bush, president of the Carnegie Institution of Washington (D. C.), and director of the Office of Scientific Research and Development. Past President Frank B. Jewett presented an outline of Doctor Bush's career declaring that: "He is a great scientist and engineer; a great teacher and administrator, and a great American in a sense that no few words can encompass. To me that greatness is the greatness of many positive personal contributions and a host of others which his leadership has inspired." The history of the Edison Medal was sketched by Chairman W. B. Kouwenhoven of the Edison Medal committee and the actual presentation was made by President

Analysis of Registration at 1944 Winter Technical Meeting

Classification	Dist. 3	Dist. 1	Dist. 2	Dist. 4	Dist. 5	Dist. 6	Dist. 7	Dist. 8	Dist. 9	Dist. 10	Totals
Members	513	261	409	61	117	2	20	2	6	26	1,417
Men guests	83	28	54	13	13	1		2		3	197
Women guests	11	5	9	5	1						31
Enrolled students	1	7	2	1		1	1				13
Totals	608	301	474	80	131	4	21	4	6	29	1,658

Analysis of Registration at Recent Winter Technical Meetings

District	1941*	1942	1943	1944
New York and foreign (3)	523	549	569	608
Middle Eastern (2)	946	349	413	474
North Eastern (1)	276	237	254	301
Great Lakes (5)	122	93	97	131
Southern (4)	27	68	22	80
Canada (10)	12	11	25	29
South West (7)	2	9	17	21
North West (9)	3	2	6	6
North Central (6)	8	7	6	4
Pacific (8)	12	6	6	4
Totals	1,931	1,331	1,419	1,658

* Held in Philadelphia, Pa.; all others in New York.

Nevin E. Funk, who presided throughout the general session. Essentially full text of Doctor Jewett's address and Doctor Bush's response appear elsewhere in this issue.

During the second half of the general session an address on the assigned topic of "The Engineer in America's Business Future" was delivered by Willard Chevalier, publisher of *Business Week* and vice-president of McGraw-Hill Publishing Company, Inc., New York. Likening the struggle between the collectivists and the individualists that began in the United States in the '30's to a game of cards, he described the "high cards" held by the two contending factions and declared that the final outcome would be determined by the people of the United States on the basis of events during the first few years after the war. He recommended a high level of employment, a high level of production, and high-production efficiency as the tripartite basis of an expanding postwar economy. The essential substance of Colonel Chevalier's address appears elsewhere in this issue under the title: "A Postwar Economy for the United States."

OTHER FEATURES

Among other features of special interest at the meeting was an evening session sponsored jointly by AIEE and the Institute of Radio Engineers which held its winter meeting in New York during the latter part of the week. Major General Roger B. Colton, chief, engineering and technical service, Signal Corps, United States Army, delivered the feature address on "Enemy Army Communications Equipment." Describing captured German, Italian, and Japanese military communication equipment, General Colton declared that: "American engineers have been instrumental in giving to the United States Army and to the Signal Corps of the Army the best equipment in the world." Further details are reported in a separate item. Supplementing General Colton's address, an array of captured enemy equipment and United States equipment was on display during the latter half of the meeting week. This exhibit, arranged by Bell Telephone Laboratories, Inc., for the Signal Corps, aroused a great deal of interest not only among those who heard General Colton's address, but also among others attending the meeting.

Comprising the final of four events sponsored during the week by the Institute's committee on education, another evening session featured an address, "Electricity on Shipboard," by Captain H. G. Rickover, head, electrical section, Bureau of Ships, United States Navy. This was of especial interest to those specially invited to earlier conferences on teaching problems associated with the Navy college training program.

Supplementing similar conferences held during previous national meetings, a conference was held this year on civic affairs and co-operation with other organizations. The discussions centered largely around local co-operative action between AIEE Sections and other local engineering groups.

Further details on the special features are reported in separate items.

An evening smoker constituted the only scheduled entertainment event of the meeting. A record total of 1,580 members and guests jammed the grand ballroom of the Commodore Hotel for this event, which comprised a dinner and entertainment.

Attendance at Sessions and Conferences of 1943 Winter Technical Meeting

	Technical Sessions		Conferences		Special Sessions	
	No.	Attendance	No.	Attendance	No.	Attendance
Monday a.m.	2	280				
Monday p.m.	2	325				
Tuesday a.m.	1	255	2	160		
Tuesday p.m.	2	335	2	200		
Wednesday a.m.					1	260
Wednesday p.m.	1	85	2	92	1	180
Thursday a.m.	1	200	2	165		
Thursday p.m.	3	477				
Thursday eve.					1	745
Friday a.m.	1	80			1	50
Friday p.m.	1	110	1	75		
Friday eve.					1	250
Totals	14	2,147	9	692	5	1,485
Average attendance		154		77		297

DIRECTORS AND COMMITTEES MEET

As usual during winter meeting week the AIEE board of directors and the national nominating committee met. The board meeting is reported elsewhere in this issue; the official nominees for 1944 election to national Institute offices selected at the meeting of the nominating committee were published in the February issue (*page 65*). Meetings of the following committees and subcommittees also were held:

Committees

AIEE Sections; land transportation; power generation; electrical machinery; Lamme Medal; membership; communication; safety; Standards; automatic stations; electronics; domestic and commercial applications; electrochemistry and electrometallurgy; Engineering Foundation–AIEE Research Project on Insulating Oils and Cable Saturants; electric welding; Student Branches; education; finance; publication; planning and co-ordination; power transmission and distribution; air transportation.

Subcommittees

Lightning arrester; insulation resistance; power-system applications of carrier current; protective devices chairmen; lightning and insulator working group; electrical hazards to farm animals; Standards co-ordinating committee 4; industrial control; industrial distribution systems guide; voltage transients in arc-furnace circuits; working group on fuses; stationary contact surfaces of standards co-ordinating committee 7; working group on Standard 20; relay; mercury-arc rectifiers; dry-plate rectifiers; transformer; nomenclature and graphical symbols; circuit-breaker standards.

Available reports of these committee meetings are included in separate items.

WINTER MEETING COMMITTEES

Chairman of the general committee for the 1944 winter technical meeting was J. F. Fairman; other members included W. J. Barrett, F. A. Cowan, J. L. Callahan, M. D. Hooven, C. R. Jones, R. A. Jones, F. V. Magalhaes, and C. S. Purnell.

The smoker committee consisted of W. R. VanSteenburgh, *chairman;* Carl Bolles, A. J. Cooper, T. C. Duncan, H. E. Farrer, J. B. Harris, Jr., C. T. Hatcher, William Jordan, E. G. D. Paterson, W. H. Rodgers, T. I. Rogers, H. B. Snow, T. W. Stauber, D. W. Taylor, and E. F. Thrall.

The committee responsible for arranging the joint AIEE–IRE session was comprised of: H. A. Affel, Austin Bailey, E. J. Content, F. B. Llewellyn, Lieutenant Colonel C. J. McIntyre, L. G. Pacent, and B. E. Shackelford.

Board of Directors Meets During Winter Technical Meeting

Appointment of a committee by the president to study conditions affecting security of employment and compensation among electrical engineers, with special reference to problems of collective bargaining was authorized by the AIEE board of directors at its regular meeting at Institute headquarters, New York, January 27, 1944 (for details see item elsewhere in this issue).

A resolution was adopted, in accordance with section 26 of the bylaws, setting the place and date of the 1944 annual meeting of the Institute at St. Louis, Mo., Monday, June 26. Chairman B. D. Hull of the 1944 AIEE summer technical meeting committee reported the plans of the committee for the meeting to be held in St. Louis, June 26–30. The plans were approved.

The committee on planning and co-ordination reported on certain suggestions which had been referred to it and its conclusions that these suggestions should not be adopted at the present time. Briefly, the suggestions were for the engagement by the Institute of a publicity expert, the establishment of a new office of vice-president to represent all foreign members and Sections (except Canada), and the establishment of a civic affairs committee. The board approved the recommendations of the committee on planning and co-ordination.

Upon request of the Districts concerned and recommendation of the committee on planning and co-ordination, District meetings were authorized as follows: North Eastern District meeting in Buffalo, N. Y., in the late spring of 1945—date to be determined by the executive committee of the District; Southern District meeting in the fall of 1945—date and place to be determined by the executive committee of that District.

A communication from The Institution of Engineers, Australia, was presented, conveying cordial and sincere greetings to the members of the AIEE and a warm invitation to those of them on service in Australia to avail

themselves of the facilities of that Institution—meetings, publications, reference libraries. The board adopted a resolution expressing its appreciation of the invitation and thanks for the hospitality which has been extended to AIEE members and extending similar privileges to the members of The Institution of Engineers, Australia, serving in or passing through the United States.

Upon recommendation of the finance committee, a resolution was adopted continuing during the year beginning May 1, 1944, the provision for granting members in countries affected by abnormal exchange rates, in payments of membership dues and subscriptions and purchases of Institute publications amounting to two dollars or over, an exchange allowance corresponding to the difference between the New York exchange value and the normal par value of the payment, such allowance not to exceed 60 per cent of the bills payable.

T. H. Morgan and I. Melville Stein were reappointed the representatives of the Institute on the council of the American Association for the Advancement of Science for the year 1944.

Following the recommendations of the officers of the Section and the Sections committee, the board voted to remove the Midwestern Canada Section (formerly Saskatchewan Section) from the list of operating Sections of the Institute, in view of the inactivity of the Section due to unusual conditions.

Upon recommendation of the Sections committee, the vice-presidents of the South West District and the Southern District, and the Memphis, North Texas, and Tulsa Sections, the following actions were taken:

Unassigned territory in the State of Arkansas allocated and District and Section boundary lines adjacent to the area rearranged as follows:

The following 39 counties were assigned to the Memphis Section and transferred from District 7 (South West) to District 4 (Southern): Arkansas, Ashley, Bradley, Calhoun, Chicot, Clark, Clay, Clebourne, Cleveland, Conway, Dallas, Desha, Drew, Faulkner, Fulton, Garland, Grant, Greene, Hot Springs, Independence, Izard, Jackson, Jefferson, Lawrence, Lincoln, Lonoke, Monroe, Perry, Prarie, Pulaski, Quachita, Randolph, Saline Sharp, Stone, Union, Van Buren, White, Woodruf.

The following 13 counties were assigned to the Tulsa Section: Baxter, Boone, Carroll, Franklin, Johnson, Logan, Madison, Marion, Montgomery, Newton, Pope, Searcy, Yell.

The following six counties were assigned to the North Texas Section: Columbia, Hempsted, Lafayette, Miller, Nevada, Pike.

The following three counties were transferred from the territory of the Tulsa Section to that of the North Texas Section: Howard, Little River, Sevier.

A report was presented by the special committee appointed by action of the board of directors at its meeting on June 24, 1943, to study the use of dues paid by Members-for-Life, and the board adopted recommendations of the committee that the voluntary dues payments by Members-for-Life be kept in a separate fund in the custody of the treasurer of the Institute, such fund to be suitably designated to indicate its source; that the fund and its proceeds be used only for such special purpose or purposes as will aid the objectives of the Institute; that at least 25 per cent of each year's receipts be retained as an addition to the "capital" part of the fund for application to a nonrecurring project deemed suitable for financial support, the remainder of the yearly receipts being available for such annual recurring or other projects as may be established; and that a suitably designated standing committee be appointed which will have complete and sole administration of the fund and the particular purpose or purposes for which it may be used.

Other actions by the board, included the following:

Actions taken in accordance with recommendations of the Standards committee:

AIEE representatives appointed: L. C. Ilsley for a two-year term beginning January 1, 1944, on the American Standards Association Mining Standardization Correlating Committee (reappointment); D. K. Frost on ASA Sectional Committee *C6*, "Terminal Markings for Electric-Power Apparatus," (to replace R. S. Elberry, Jr.; appointment subject to acceptance of Mr. Frost's application for membership); M. S. Coover, E. H. Martindale, and Sidney Withington on ASA Sectional Committee *C64*, "Carbon, Graphite and Metal-Graphite Brushes"; A. B. Campbell as alternate representative on Sectional Committee *C2*, "National Electrical Safety Code"; Gilbert D. McCann, Jr., on Sectional Committee *C5*, "Code for Protection Against Lightning," (to replace A. M. Opsahl).

Approved the addition of a third sponsor, the National Fire Protection Association, for Sectional Committee *C5*, "Code for Protection Against Lightning," (the other two sponsors being the National Bureau of Standards and the AIEE).

Approved for immediate publication a revision, prepared by the committee on marine transportation, of the pamphlet 45-*A* of April 1, 1943, "Modification of and Supplement to AIEE Standard 45—Recommended Practice for Electrical Installations on Shipboard."

Approved for publication as an AIEE Standard, a report, with certain approved revisions, prepared by the committee on protective devices, on "Capacitance Potential Devices and Outdoor Coupling Capacitors" (AIEE Standard 31), which was published in December 1941 as a proposed Standard for trial use.

Approved for submission to ASA with recommendation for approval as American Standards: Report of Sectional Committee *C62*, "Lightning Arresters," (AIEE Standard 28), and report of Sectional Committee *Z32.10*, "Graphical Symbols for Electronic Devices."

Actions of the executive committee reported and confirmed: As of November 24, 1943, five applicants transferred and one elected to the grade of Fellow; three applicants transferred and 19 elected to the grade of Member; 78 applicants elected to the grade of Associate; 241 Students enrolled. As of December 29, 1943, four applicants transferred and one elected to the grade of Fellow; 66 applicants transferred and 22 elected to the grade of Member; 134 applicants elected to the grade of Associate; 257 Students enrolled.

Reports were presented and approved of meetings of the board of examiners held November 18, and December 22, 1943, and January 20, 1944. Upon recommendation of the board of examiners, the following actions were taken: five applicants were transferred to the grade of Fellow; 28 applicants were transferred and 34 were elected to the grade of Member; 146 applicants were elected to the grade of Associate; one Associate was reinstated; 158 Students were enrolled.

Monthly disbursements were reported by the finance committee and approved as follows: November, $29,274.15; December, $29,519.05; January, $24,869.45.

The board adopted a resolution expressing its appreciation of the arrangements made by the technical program committee, the winter technical meeting committee, and the smoker committee for an outstanding program for the 1944 winter technical meeting of the Institute.

Those present were:

President—Nevin E. Funk, Philadelphia, Pa.

Past Presidents—H. S. Osborne, New York; D. C. Prince, Schenectady, N. Y.

Vice-Presidents—A. G. Dewars, Minneapolis, Minn.; W. J. Gilson, Toronto, Ont.; C. R. Jones, New York; E. T. Mahood, Kansas City, Mo.; K. B. McEachron, Pittsfield, Mass.; C. W. Ricker, New Orleans, La.; E. W. Schilling, Bozeman, Mont.; W. E. Wickenden, Cleveland, Ohio.

Directors—T. F. Barton, New York; M. S. Coover, Ames, Iowa; C. M. Laffoon, East Pittsburgh, Pa.; T. G. LeClair, Chicago, Ill.; F. R. Maxwell, Jr., Pensacola, Fla.; C. W. Mier, Dallas, Tex.; S. H. Mortensen, Milwaukee, Wis.; W. B. Morton, Philadelphia, Pa.; W. R. Smith, Newark, N. J.; R. G. Warner, New Haven, Conn.

National Treasurer—W. I. Slichter, New York.

National Secretary—H. H. Henline, New York.

Conferences Held on Temperature Ratings of Continuous-Duty and Intermittent Machines

Two conferences on the measurement of permissible temperature rises on electrical machines were conducted at the 1944 AIEE winter technical meeting, January 25, in New York, N. Y. Seven informal papers were presented at the morning conference, devoted to measurement of temperature rise in continuous-duty machines. C. E. Kilbourne (M '37) chairman of the AIEE subcommittee on d-c machinery, presided. J. F. Calvert (M '35) vice-chairman of the AIEE committee on electrical machinery, conducted the afternoon session on permissible temperature rises of short-time rated machines.

CONTINUOUS-DUTY MACHINES

The purpose of this conference was to develop factual information through actual test reports which might be used in reaching conclusions concerning the adoption and revision of standards of permissible rise by resistance for all windings of continuous-duty machines. The present American Standard *C-50*, "Rotating Electrical Machinery," approved March 29, 1943, recognizes the resistance method of temperature determination only to the extent of establishing standards for shunt-field windings. Basic to all the discussions and reports was the Memorandum on Addendum to American Standard *C-50*, issued by the AIEE Standards co-ordinating committee 4, P. L. Alger (F '30) chairman.

Mr. Alger, addressing the group before the presentation of the papers, explained that the thermometer method had been established as standard because, at the time, complete information was lacking as to the accuracy of resistance measurements. In view of the fact that railway motors are standardized already on the resistance method, and that it is used broadly in Europe, the committee considered it necessary that proper limits for the resistance method be established which can be used optionally by the manufacturer. The committee tentatively suggested limits of 65 and 100 degrees centigrade for class-*A* and *B* insulated machines, respectively.

The conference papers evidenced considerable divergence of opinion. Some papers supported the greater accuracy of the rise by resistance measurements for determining internal temperature, whereas others indicated that rises by thermometer or thermocouple give better approximations

of the hot-spot temperature of the machine.

The general opinion at the end of the conference tended to the following conclusion: Granted, that the rise by resistance method of temperature measurement, performed with the proper technique, was the more accurate; even so, is an average value desirable in establishing permissible temperature ratings that will protect the insulation life of the machine? Should not efforts be made to determine a method which gives a result more closely related to the hot-spot or maximum temperature, since this temperature is the one that causes deterioration and breakdown? On the basis of the wide discrepancy in the ratios of rise by resistance to rise by thermometer found in the several papers presented, it was generally agreed that further less controversial tests would be necessary before any adoptions or revisions to standards could be made. A brief summary of each of the papers follows.

To establish the facts before the conference, F. A. Compton, Jr. (A '39) General Electric Company, Erie, Pa., reviewed the pertinent high lights of his paper, "Temperature Limits and Measurements for Rating D-C Machines" (*AIEE Trans., Dec '43, pp 780–5*). According to his experience, tests using resistance measurements, with improvements in technique, have disclosed different temperatures than those indicated by thermometers. On the basis of this observation and the fact that greater accuracy and consistency can be achieved with the resistance method, he recommended that the rise-by-resistance method be used more generally, and that ultimately it should be recognized in the Standards, as is now the case for railway motors.

In the tests reported by L. E. Miller (M '36) Reliance Electric and Engineering Company, Cleveland, Ohio, conditions contradicting those in Mr. Compton's paper were presented. Mr. Miller took issue with Mr. Compton's conclusions on the basis that (1) the results obtained were not general and that (2) the proper differential to be assigned is still a debatable question. In the tests which Mr. Miller reported, the recorded temperature rise of the armature by resistance would have been from four to eight degrees less than the thermometers showed actually existed. However, Mr. Miller stated that his resistance measurements were taken five to ten minutes after shutdown and were not corrected to the instant of shutdown as Mr. Compton's were. This may account for some difference, he admitted.

Mr. Miller further brought out that such results are not general but are particularly true of d-c armatures operating with a high degree of ventilation, since the heat dissipation, in such cases, may be much greater in one part of the armature than in another.

"It is believed," he said, "that the ratios of temperature rise by resistance to temperature rise by thermometer depend more or less on the type and design of machine. With variations in design and manufacture, an average temperature cannot be substituted for a rise in the hottest observable part unless one is willing to ignore the effect of temperature on the insulation of that part."

On seven recent tests of continuous, open, industrial d-c motors, C. B. Hathaway (A '40) Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., reported that the average rise by the resistance method was 38 per cent higher than that measured by thermometers. On 63 tests of induction motors the average temperature rise by the resistance method was 29 per cent higher than that by thermometer for open machines and 18 per cent higher for closed machines. In neither test group did the results indicate any discernible relation between the differences in the two methods and the size and speed of the motors.

Shown at the winter technical meeting are A. H. Frampton, Hydro-Electric Power Commission of Ontario; J. B. MacNeill, chairman of the AIEE protective devices committee, who presided at the session on relays; and J. F. Fairman, chairman of the AIEE winter technical meeting committee

Mr. Hathaway's conclusions were as follows: "If it can be assumed that the temperatures as recorded by the thermometers are correct and that the resistance readings are accurate, then the variation of the difference obtained by the two methods derives from causes which we do not recognize. It has been the experience of our company that we are able to predict within a few degrees by thermometer the temperature rise of a new design. Therefore, until we develop our knowledge of temperature rises by resistance to the same point, we feel it unwise to embark on a general policy of making guarantees by this method."

T. E. M. Carville (M '32) Westinghouse Electric and Manufacturing Company, Lima, Ohio, confined his comments to fractional-horsepower motors. "Recent plant tests," he said, "have yielded a ratio of rise by resistance to rise by thermometer of 1.17 for single-phase motors and 1.22 for totally enclosed polyphase motors. If 60 degrees centigrade rise by resistance be adopted, the corresponding rise by thermometer should be 50 degrees centigrade to agree with these ratios. However, it is recommended that 55 degrees by thermometer reading be retained and the proposed 65 degrees centigrade by resistance measurements be allowed."

Mr. Carville also recommended that the proposed revision to the Standard, authorizing the optional use of the rise-by-resistance method, be amended to include recognition of the thermocouple method as applicable to fractional-horsepower motors. The values for the surface thermocouple method should be the same as the values by the resistance method, as was demonstrated by accompanying data. However, the standard for surface thermocouple measurements should be set up so that customers who insist that the thermocouple method be used will not expect the same limit as that set for the thermometer method. Comparison of tests on d-c and a-c machines showed the need for higher resistance values for d-c machines, a need consistent with past performance records.

A paper by H. L. Smith (F '42) Louis Allis Company, Milwaukee, Wis., who was unable to be present, was read by T. M. Linville (M '34) conference secretary. The results of the test data indicated that much more refined methods must be used for resistance measurements, as indicated by the wide variation in results, although they were found to be fair checks as to thermometer readings on different motors of the same design. The only general conclusion advanced was that present resistance measurements of the armature and interpole circuits are not accurate enough to be used independently, and that the more accurate shunt-field data would indicate a rise by resistance around 20 degrees centigrade higher than that by thermometer.

A paper presented by M. A. Baker (A '42) General Electric Company, Fort Wayne, Ind., included test data to support the coordinating committee's recommendation of higher limits, and showed how conservatively chosen the proposed values are. The existing and proposed ratios for rise by resistance to rise by thermometer, and the maximum, mean, and minimum test ratios were given in a pair of tables. The tabulations, interpreted graphically, showed plainly that the users of d-c machines are dependent upon the manufacturers to avoid unsatisfactory temperatures and that the thermometer test is variable.

R. H. Norris presented a paper prepared jointly by himself and F. Burggraf, both from General Electric Company, Schenectady, N. Y. Charts were exhibited showing it is an error to reason that thermometers placed on the rotor windings of d-c machines giving maximum readings four to five minutes after application show anything more than the temperature of the core iron. Actually the iron temperature is 50 to 70 per cent of the mean copper temperature at the instant of shutdown. A cooling curve was exhibited showing that initially the copper in the core portion cools to iron temperature, and this is followed by cooling of the end windings to iron temperature, and finally by cooling of the rotor mass by free convection. For an accurate test using the resistance method, Mr. Norris stated that the first reading should be taken one to one and one-half minutes after shutdown, and the curve should be extrapolated back to the instant of shutdown to arrive at the mean copper temperature during operation. He proposed that the ratio between allowable rise by resistance and that by thermometer for class-*B* machines be 1.43, and stated that both the theoretical results and tests given for ten machines showed that this ratio is suitable for present d-c machine design practice.

Following the general discussion F. E. Harrell (F '40) chairman of the AIEE committee on electric machinery, concluded the conference with an enjoinder to the committee to determine new engineering facts on hot-spot temperatures and their relation to the results with thermometers, thermocouples, and resistance methods, and to derive therefrom and establish safe performance levels.

SHORT-TIME RATED MACHINES

Three hours on Tuesday afternoon were devoted to studying permissible temperature rises of short-time rated machines. This conference likewise stemmed from Mr. Alger's Memorandum on Addendum to American Standard *C*–50, in which he proposed new limits for temperature rise by resistance on intermittent-rated machines, both a-c and d-c, including fractional- and integral-horsepower sizes.

Mr. Alger opened the conference with a summary of the questions on the agenda. He stated that the two important problems before the conference were (1) to determine what the temperature limits really should be and (2) to ascertain the relation of time to rated input. What should be included on the name plate of a machine was another consideration. Mr. Alger advanced the suggestion of marking the continuous rating and the maximum allowable input, or torque. Some further discussion was presented with reference to how and where the temperature can be determined best—whether by resistance, thermometer, or thermocouple.

The five informal papers which were presented thereafter provided considerable factual information of varying nature and a stimulus for open discussion. F. A. Compton, Jr., referring to his paper, "Temperature Limits and Measurements for Rating D-C Machines," illustrated by representative, or average, test curves the difference between resistance and thermometer readings versus hours running for various machine sizes. Although a ten per cent differential is recognized, his tests showed the differential to be much greater. His data pointed to the conclusion that the resistance method of temperature measurement was the best and most accurate, but that higher values should be adopted for the differential.

L. E. Miller commented on the preceding paper thus: "Mr. Compton . . . . . advances the idea that the short-time rating of d-c machinery is merely a gauge giving the user a conception of the physical size and torque capacity of the motor, but conveys nothing regarding the thermal capacity upon which the satisfactory life of the insulation depends. We entirely concur with this idea and further agree that the careful application of such motors, taking into account the duty cycle and the continuous thermal capacity has considerable effect upon the insulation life.

The fact that two motors of different design are capable of meeting the same short-time rating but have entirely different rms capacities over a continuous period of time indicates the desirability of another form of rating so that the application engineer can apply motors intelligently to intermittent drives. Although we have no solution to offer as yet, we feel the problem should be studied."

C. B. Hathaway reported that on a given machine there seemed to be a definite relationship between the temperature rise by resistance and that by thermometer, but that, in the experience of his company one could not follow this through even on a line of similar machines, to say nothing of a group of machines of varying size and design.

T. E. M. Carville pointed out that since the values of temperatures by the various methods of measurement on continuous-rated motors appear to be percentages of the temperature rise rather than of the temperature differences between the two methods, it would be desirable to have the information calculated on the basis of actual temperatures. He also proclaimed a need for further tests on fractional-horsepower motors by the three methods for 15, 30, and 60 minutes before changing the limits. Actually, he concluded, short-time-rated motors are applied on a duty-cycle basis rather than on their rating. The rise by thermometer should not be changed but rather the rise by other methods should be determined and recognized.

W. R. Hough (M '41) Reliance Electric and Engineering Company, Cleveland, Ohio, concluded from an analysis of his test results that for totally enclosed machines it is illogical to have the differential between temperature rise by resistance and temperature rise by thermometer as a fixed increment independent of the rated temperature rise of the motor; a fixed ratio between the limits for the two methods would more closely match actual conditions in the range of rated temperatures. Mr. Hough also reported that, on the basis of his test results, the values proposed by Mr. Alger for the ratios of temperature rise by resistance to that by thermometer for half-hour-rated motors appeared too great. He suggested that the ratio fall within the range of 1.15 to 1.25. So few tests were made on open motors that no conclusions were derived therefrom.

It was brought out further that if the first readings on resistance–time curves are not taken within one minute after shutdown, the data obtained by extrapolating back to zero time is not a good approximation of true conditions. The over-all result of the conference was an indication that present factual information is not apodictic and does not justify any dependable conclusions regarding the relative magnitudes to be expected on resistance, thermometer, and thermocouple readings.

F. E. Harrell (F '40) chairman of the AIEE committee on electrical machinery, made a few summary remarks before dismissing the conference. He expressed the intention of encouraging the presentation of papers during the next 6–12 months on the general subject of hot-spot temperatures and intermittent loads.

Forecasting of Load Demands Occupies Application Conference

Load demands from military-camp and low-cost-housing installations; an explanation of qualities peculiar to nickel–chromium alloys seldom taken into account in specifications; a short introduction to panel space heating; a method of combating vibration in electrical contacts; and a survey of secondary protective devices were the diverse topics of discussion at the conference on domestic and commercial applications held during the recent AIEE winter technical meeting.

In his paper, "Data on Electric Loads of Wartime Projects," O. B. Falls, Jr. (A '39) General Electric Company, Schenectady, N. Y., presented data on electrified mess halls and on low-cost housing developments which he considered portentous: the first for any institution preparing food for large numbers of people, and the second for postwar planning of distribution systems in general.

Mr. Falls explained that his final load and demand factors for the mess hall were appreciably lower than those obtained in previous tests made of electric cooking loads in military establishments, because of the practice, in the particular hall studied, of turning on all food-preparation appliances and ovens at one time to keep the food warm. This produced a rather high peak for a short time. Mr. Falls believed that his lower figures for the watt-hours consumed per man and the average diversified watts per man reflected the greater efficiency of preparing food for larger numbers of men, as previous tests were made in camps having individual mess halls and kitchens for each barrack.

Mr. Falls classified his data covering a low-cost housing development occupied entirely by enlisted personnel to conform to curves on diversified kilowatt demand and kilowatt-hour consumption prepared for three groups of conventional houses and other low-cost developments. The three groups studied were: houses that were completely electrified (*A*); houses lacking only electric water heaters (*B*); and houses lacking both electric water heaters and ranges (*C*). As was expected, the demand for the project studied by Mr. Falls was lower than for the conventional housing for both the *A* and *B* groups. However, for the *C* group the demand was higher than in the conventional-housing studies.

In an attempt to estimate the influence of modern design of appliances on load demand, Mr. Falls compared groups *A* and *B* which represented a difference in demand due to water heaters. The relative difference between these groups was the same for the older studies and the more recent one. The water heaters in all studies were similar in design. In the comparison of groups *B* and

C which represented a difference in demand due to the electric range, there was a disparity between Mr. Falls' data and those of the older studies with the difference in demand between Mr. Falls' *B* and *C* groups relatively greater. As the ranges installed in the later project were of more recent design, Mr. Falls concluded that modern appliances can be expected to add less to the peak load than older types.

Letters from Mortimer Foster of the War Production Board and J. D. Brooks (A '41) of the Federal Housing Authority, praising Mr. Falls' efforts were read. Mr. Foster added that the diversity in plans submitted to him resulted from either lack of load-demand data, or necessity for haste, or lack of appreciation of the now permanent need for extreme economy. The basic problem in his opinion is transformer-capacity estimation since revision upward or downward to correct errors in load assumption has become the rule.

One discusser raised the question of costs in any projected electrification by pointing out the greater number of British thermal units obtainable from oil or gas for one cent. He added that he thought perhaps more consideration should be given to electrifying the frying pan, for example, instead of the range.

M. K. Brody (M '42) *McCall's Magazine*, New York, disputed this point by suggesting that the important consideration from the consumer's viewpoint is not the number of heat units he can buy for his cent but the amount of work he can perform for his unit of expenditure. Mr. Brody read comments on Mr. Falls' paper from B. M. Jones (F '42) and C. N. Clark (A '36) Duquesne Light Company, Pittsburgh, Pa. In the territory served by the Duquesne company, power had been supplied to low-cost housing developments without water heaters or electric ranges at four kilovolts from the existing distribution system with some extensions and minimum of reinforcing. The housing projects owned the primary distribution system within their bounds as well as all transformers, secondary systems, and in some cases street lighting equipment.

S. B. Williams (M '37) *Electrical World*, New York, proposed establishment of a load-research foundation perhaps by co-operation among power companies. Given a set of conditions, the engineer should be able to forecast demand, he said.

R. E. Hanson, Ebasco Services, New York, read a discussion prepared by W. F. Friend which declared that data such as Mr. Falls' may be expected to elucidate trends of post-war utilization when political considerations as well as surplus generating capacity tend toward further lowering of residential rates. He noted that the spread between maximum and minimum demand diminishes with the decrease in electrical facilities and supplied the results of a survey of the consumption of the average conventional dwelling using appliances marketed before Pearl Harbor. The survey revealed that the low-cost-housing consumption fell below the conventional consumption except where complete electric service was supplied. Further analysis showed that the water heater may be the chief cause of the inconsistency in the consumption data. Stating that some of the projects studied by Mr. Falls were so far in excess of normal in their demands as to be atypical examples of low-cost housing, Mr. Friend suggested that future studies should include: percentage of occupancy for the whole project, number of persons in average family, wage level of tenants, such building characteristics as presence of basement, insulation, quality of construction, kind of space-heating system, and fuel used, type of major kitchen appliances including automatic controls, type of electric rate (that is, whether wholesale metered and included in the rent or retail metered and paid as a separate bill by the tenant), and average unit cost.

W. A. Gatward, Hoskins Manufacturing Company, prefaced his paper, "Some Peculiar Features of Nickel Alloys," with the aside that the natural inclination of engineers to overload every piece of equipment presents a constant problem to the manufacturer. He confined most of his paper to consideration of the alloy of 80 per cent nickel and 20 per cent chromium which is standard for use in the manufacture of electric heating devices. Mr. Gatward spoke first of some problems arising for the manufacturer of nickel–chromium alloy from his desire to perfect his own product; secondly, he named five problems resulting from the demands of the user. The major interests of the user, he said, in the durability of the material and the wattage of a heating element when it is at operating temperature are interrelated with the resistivity of the metal at room temperature, the cross-sectional area or size, and the change in resistance when the element is heated. To meet these demands the producer must solve the following problems:

1. For every heavy wire or strip, the cross section can be measured more accurately and conveniently than the resistance per foot.

2. For small wires and ribbon, the ohms per foot can be measured more accurately than the cross section.

3. The utmost life must be obtained from the costly diamond dies which are worn quickly in drawing small wires.

4. The shape of the cross section of the ribbons of wire is not rectangular but thicker in the center and rounded at the edges, and therefore measurement is difficult.

5. The whole resistance problem is complicated by a peculiar effect of the rate of cooling on the resistivity.

The user would aid in solving the first three problems if he were to specify resistivity and ohms per foot, both with suitable limits, and say nothing about size tolerances. The size would then be consistent with the tolerances on the other two items. The fourth problem would vanish if the user would not tie the producer down to close tolerances on ribbon thickness, since this is measured by a weighting process not completely accurate. The fifth problem arises when the specifications allow too little resistivity tolerance. The resistivity of the metal at a given high temperature is more stable than at room temperature. Heavy wire is cooled more slowly than fine wire. Even though both are made from the same metal lot which has a resistivity at 1,600 degrees Fahrenheit of 160 ohms per circular-mil-foot, the fine wire will finish with a resistivity of about 620 and the heavy wire with about 655. When heated to 1,600 degrees Fahrenheit, one will rise eight per cent and one only two per cent. Therefore for preliminary calculations he advised the user to employ average values which are quite accurate for the sizes of wire used in most domestic devices.

F. W. Hutchinson, University of California, Berkeley, presented a few slides and a short explanation of panel space heating in an effort to sound out the amount of interest in a paper describing a design procedure for panel space heating which might be prepared for the St. Louis meeting of the AIEE in June 1944 and for which several related papers already are scheduled. Mr. Hutchinson stated that the heating, actually a hot-water system, is not done by electricity but that most of the systems installed in Europe, particularly in England, are operated electrically. In panel-type heating, which depends on radiation for its effectiveness, the heat is radiated from walls covered with a fabric applied in strips similar in appearance to wallpaper, to a predetermined comfort zone of the room. No heat is lost in heating the walls or the air. The heat is concentrated where it will warm the human beings in the room most effectively. To an inquiry about the amount of saving effected by use of the panel heating system compared with the usual hot-water heating system, Mr. Hutchinson answered that savings of at least 10 to 15 per cent could be expected because of the lower air temperatures possible. He pointed out that savings would increase as ventilation increased.

Stephen Jones, Heinemann Circuit Breaker Company, presented the paper, "A Survey of Secondary Protection and Protective Devices." The four types of protective devices available at present, the electrothermal, electrothermal mechanical, the electrothermal electromagnetic mechanical, and the electromagnetic mechanical, were considered in the chronological order of their development. Each type was treated for its fulfillment of the primary qualifications of inverse time–overload characteristic, instantaneous trip control, low power absorption, high current-rupturing capacity, automatic operation free of the handle, resetability, tamperproof construction, maintenance of rating, high dielectric strength, least size and weight consistent with its application.

AIEE technical paper 44-69 (scheduled for publication in the April 1944 Transactions section) entitled "The Vibration of Electrical Contacts," was presented by M. N. Russell and Saul Keilien, Pass and Seymour, Inc., Syracuse, N. Y. Discussion of this paper brought out the fact that experience had proved the advantage of providing a resilient contact for operation under conditions of severe vibration. It was also stated that data obtained thus far were inconsistent and that a differentiation between domestic and commercial contacts is needed.

W. F. Ogden (M '41) chairman of the committee on domestic and commercial applications, presided at the conference.

Electrical Measurements Subject of Two Winter Meeting Sessions

Instruments for electrical measurements and their application furnished the subject of two sessions of the recent AIEE winter technical meeting, on Monday, January 24, a morning session on electrical measuring instruments under the sponsorship of the instruments and measurements committee, and an afternoon session on application of electrical measurements and basic sciences, sponsored jointly by the instruments and measurements and basic sciences committees.

C. L. Dawes, chairman of the instruments and measurements committee, presided at the morning session. Over 90 members and guests attended. In the first paper, "A Mul-

tiple-Deflection A-C Potentiometer" by R. B. Marshall (A '40) of Purdue University, Lafayette, Ind., the author described an ingenious method by which impedances from very low to very high values can be measured by an a-c-potentiometer method employing ordinary indicating instruments. The paper was discussed by P. A. Borden (M '19) of the Bristol Company, Waterbury, Conn., E. D. Doyle (F '27) and A. J. Williams, Jr. (A '27) of Leeds and Northrup Company, Philadelphia, Pa., and Walther Richter (F '42) consulting engineer, Milwaukee, Wis. Walther Richter then presented a paper, "An Instrument for the Measurement of Large Alternating Currents." The method involves a mutual inductance wound on an openable flexible nonmagnetic core which can be linked with the current to be measured. By means of a resistor-capacitor circuit and an amplifier, an accurate reproduction of large currents such as welding currents can be obtained and shown on an oscilloscope. The paper was discussed by E. D. Doyle. In a third paper, "Crossed-Coil Power-Factor Meters," presented by the author, N. P. Millar of the General Electric Company, the equations for the Tuma phase meter were first derived. From these equations, the author shows methods whereby the scales of power-factor meters for single-phase and polyphase circuits can be controlled and designed, as for example, by changing the angle between the coils and the position of the pointer. The paper was discussed by P. A. Borden, and Paul MacGahan (F '42), Westinghouse Electric and Manufacturing Company, Newark, N. J. A considerable portion of the discussion centered on the significance of power factor in an unbalanced three-phase system. The last paper of the session, "Influence of Improved Magnetic Alloys on Design Trends of Electrical Instruments" by M. S. Wilson (M '43) and J. M. Whittenton (A '37) of the General Electric Company, Lynn, Mass., was presented by Mr. Whittenton. The paper gave the permanent-magnet properties of the several alloys used for instrument magnets and showed how, with the improved alloys, the size of instruments could be materially reduced and yet the performance improved. The authors pointed out that the ideal magnet material should have high coercive force, residual induction, and available energy, and also good fabricating qualities. A material which approaches these qualifications is a new cobalt-molybdenum-iron alloy known as "Comol," although its magnetic characteristics are inferior to those of the Alnico group. By the use of this material and internal pivot construction, a compact panel-type instrument with better over-all characteristics has become available. The paper was discussed by L. W. Matsch (M '41) of the Commonwealth Edison Company, Chicago, Ill., and Paul MacGahan.

Electrical means for solving mathematical and transient-heat-flow problems was a major topic at the afternoon session. More than 100 members and guests attended the session at which T. S. Gray, vice-chairman of the committee on instruments and measurements, and R. W. Ager, chairman of the committee on basic sciences, presided jointly.

Description of a complete electric network for studies of transient heat flow was included in the first paper, "The Accuracy of Measurements in Lumped *R-C* Cable Circuits As Used in the Study of Transient Heat Flow," by Victor Paschkis and Michael P. Heisler of Columbia University, New York. The paper was presented by Mr. Paschkis, who described the inherent limitations on the accuracy of the method brought about by the leakage in the capacitors and the lumps in the circuit. R. J. Wiseman (F '27) of the Okonite Company, Passaic, N. J., discussed the paper.

A servo system that places no load or restraint on the shaft being followed was described in the second paper entitled "Polarized Light Servo System," by T. M. Berry (A '43) of the General Electric Company, Schenectady, N. Y., which was presented by the author. The presentation was clarified by a demonstration projected on the screen by a lantern-slide projector, and applications of the system to a device for studying flow phenomena through turbine passages and to a differential analyzer were mentioned. Discussion of the paper was deferred until after the presentation of the third and companion paper entitled, "A New Differential Analyzer," by H. P. Kuehni and H. A. Peterson (M '41) of the General Electric Company, Schenectady, N. Y. In his presentation, Mr. Kuehni mentioned various improvements over previous instruments including use of the new servo system described in the previous paper. The tremendous power of the differential analyzer as a mathematical tool and its importance in the war program were emphasized. Written discussions of both the second and third papers by F. J. Maginniss of the General Electric Company were read by C. Concordia (M '37) of the same company. A. E. Harrison (A '39) of the Sperry Gyroscope Company, Inc., Garden City, N. Y., R. W. Ager (M '41) of Cornell University, Ithaca, N. Y., and J. R. Pattee (M '42) of the Bristol Company, Waterbury, Conn., discussed the paper by Mr. Berry. Comments on the paper by Kuehni and Peterson were offered by C. N. Weygandt (A '37) of the University of Pennsylvania, Philadelphia, Pa.; H. Poritsky of the General Electric Company; E. W. Kimbark (M '35) of Northwestern Technological Institute (on leave at the Massachusetts Institute of Technology, Cambridge, Mass.); and E. S. Lee (F '30) of the General Electric Company, Schenectady, N. Y. The discussion of the two papers was closed by Berry and Peterson.

Under the sponsorship of the committee on basic sciences, a paper entitled "Symmetrical-Component Analysis of the Four-Phase System," by A. Boyajian (F '26) of the General Electric Company, Pittsfield, Mass., was presented by C. Concordia of the same company. It stressed a new basis for symmetry among the members of the sets of components. A written discussion of the paper by A. N. Garin (M 37) of the General Electric Company, Pittsfield, Mass., was read by G. Camilli (F '43) of the same company. Further discussion was offered by E. W. Kimbark, followed by closing remarks by C. Concordia.

The final paper entitled "Some Aspects of Inductance When Iron Is Present," by L. T. Rader (A '34) and E. C. Litscher of the General Electric Company, Schenectady, N. Y., was presented by Mr. Litscher. Wide disparity of results may occur in a particular problem depending on which of the various definitions of inductance is used in its solution. The significance of the definitions and their use in the analysis of different applications were described. The paper was discussed by C. Concordia, Walther Richter, and E. H. Vett, University of Illinois, Urbana.

(C. L. Dawes, chairman, and T. S. Gray, vice-chairman, AIEE committee on instruments and measurements.)

Needs of Industry Stressed at Power-Application Conference

Motor control, circuit breakers, lightning protection, plant distribution systems, and induction heating were the subjects discussed at the conference on industrial power applications held recently during the AIEE winter technical meeting. Herbert Speight, vice chairman of the AIEE committee on industrial power applications, opened the meeting; after the presentation of the first paper, he introduced R. C. R. Schulze, chairman, subcommittee on service and switching, who presided thereafter.

The first paper (44-18) on the program was "Inverter Action on Reversing of Thyratron Motor Control," by H. L. Palmer and H. H. Leigh (A '39), both of General Electric Company, Schenectady, N. Y. This paper is scheduled for future publication in the Transactions section of *Electrical Engineering*. Two papers listed for this conference were not presented because of the absence of their authors.

L. C. Peterman, of Ford, Bacon, and Davis, Inc., New York, stated that his paper, "Experience With Short Circuits and Breakers," was concerned primarily with circuits of 600 volts and less. The short circuits and low-resistance grounds discussed were only those developed from defective or damaged equipment. The author pointed out that, in the low-voltage field where direct-acting breakers have greater operating speed than any high-speed relay and oil-breaker combination, there have been no real developments in securing selectivity and adequate co-ordination. Mr. Peterman objected to the manufacturer's advocating the cascading of breakers in order to protect a low-voltage system, characterizing this as unsound engineering. Although this arrangement is more economical, the management of the plant is likely to ignore the monetary saving when it discovers that cascading may cause the entire plant to shut down. Mr. Peterman stated that the most urgent needs in industrial plants are adjustable trip ratings for all types of breakers and true and dependable selectivity coupled with high-speed tripping from direct-acting mechanism. The author said that availability of these items will widen the field for the application of low-voltage breakers to all industrial plants.

B. M. Jones (M '42) Duquesne Light Company, Pittsburgh, Pa., in his discussion of Peterman's paper, agreed with the basic fundamentals therein. He stated that a sound engineering analysis of the subject should be made, and that he thought selectivity is just as essential on low-voltage circuits as on high-voltage circuits.

The general theme of the third paper on the conference program was protection against lightning for industrial equipment in coal mines, as reported by A. C. Muir (M '39) Berwind-White Coal Mining Company, Philadelphia, Pa. In his presentation, the author compared the early use of electric mine locomotives and oxide-film lightning

arresters with the improvements and developments of equipment and protection of today.

"Beginning in 1937," Mr. Muir continued, "pellet-type distribution arresters were installed on the lines and protective capacitors were installed on the 6,600-volt busses. The electrolytic and oxide-film arresters have been taken out as their condition warranted and replaced by station-type Thyrite arresters. Originally lightning protection consisted of one arrester at each station. Several years ago, new protective equipment was installed at these mines" (Minden, W. Va.). "Thyrite station-type arresters were installed on the 2,300-volt busses at the station. Protective capacitors were installed. Pellet-type distribution arresters were installed on the transmission lines leading to the substations. Before putting in the modern protection, we had several machines out of service each season because of lightning. No machines were damaged the first year the equipment was installed, and we have had only two failures since then due to lightning."

Mr. Muir stated that protection of the a-c rotating equipment has been obtained by combining overhead ground wire with frequent ground connections, pellet-type distribution arresters on the lines, and protective capacitors and station arresters at the stations. At least there has been less trouble attributable to lightning since the installation of such protective devices.

One of the most constructive discussions of Muir's paper was presented extemporaneously by W. H. Collins (M '30) Board of Water and Electric Light Commissioners, Lansing, Mich., who stated that he was interested in lightning protection in the distribution field. He confirmed the content of the paper as being in keeping with his experience in that field. Mr. Collins commented on the delayed discovery of these protective devices and on the fact that lightning arresters still are not being used in industry to full extent. There is no sound reason for industry not to utilize arresters, as they are an inexpensive form of protection, and there is a definite need for further safety.

A paper concerned with the wartime changes being made in the distribution systems of industrial plants was read by A. F. Bowers, General Electric Company, Philadelphia, Pa., who assisted C. E. Smith, New York Shipbuilding Corporation, New York, N. Y., in the preparation. The theme of the paper consisted of the rapid expansion of industrial plants in this wartime era and the complications of extending distribution systems in these plants. "Cost became secondary to time," Mr. Bowers stated. "The design depended on the availability of materials, equipment, labor, the design of the existing system, and the necessity of maintenance of service during the period of the expansion program." Examples of specific instances of reconstruction in a large shipyard were included.

The final paper to be presented at the conference was "Induction-Heating Applications," by Howard E. Somes, Budd Induction Heating, Inc., Detroit, Mich. Mr. Somes reported that induction-heating applications primarily must be divided into two groups: nonselective heating and local or differential heating. "In general," the author claimed, "nonselective heating is useful for paint drying, annealing, forging, and like applications. . . For local or differential heating, electromagnetic induction or flame represent the two outstanding means of selective heating." In the application of nonselective-type heating, especially for forging, Mr. Somes declared that the Budd Company considers that its many advantages, such as savings of material and reduced cost of scale removal, more than offset the increased cost of electric energy which must be supplied as a source of heat.

The author illustrated verbally several methods of utilizing induction heating by his company. Among them were:

1. The brazing of a burster tube into a shell body.

2. Selective heat treatment of tubular bodies, such as internal-combustion-engine cylinder liners, compressor cylinder liners, slush-pump cylinder liners.

3. Hardening of tank track pins, piston pins, and other small parts.

Mr. Somes concluded his paper by stating that "The science or art of heat treatment is today a very vital and important part of industry. The future growth of induction heat treatment will be contingent largely on the close co-operation between the designing engineer, the metallurgist, the heat treater, and the electrical industry."

Administrative Problems of the ASTP and NCTP Discussed

An open conference was held on the afternoon of January 28 at the AIEE winter technical meeting for discussion of the problems encountered in the administration of the Army and Navy Specialized Training Programs. Robin Beach (F '35) chairman of the AIEE committee on education presided over the session, which was attended largely by engineering professors from the colleges and universities at which the programs are being discharged.

Lieutenant Colonel F. H. Pumphrey (M '25) chief of the engineering division, Army Specialized Training Division, and Commander A. S. Adams, USN, retired, with the Bureau of Navy Personnel, Washington, D. C., led the discussion after reviewing the aims of the respective programs and their development thus far. Colonel Pumphrey took the floor for the Army first, and outlined certain anticipated changes in the ASTP for which final approval was expected shortly before being formally announced. The alterations were based on recommendations derived from the experience of the participating institutions and were incorporated in a revised curriculum to become effective for advance-phase engineering students in all terms on or about April 1.

According to Colonel Pumphrey, in setting up the ASTP, the first requirement that seemed indicated was training in leadership—in the ability to analyze a local situation, to draw accurate conclusions, and to initiate effective action. When the advanced-phase engineering curricula were prepared originally, extensive training in problem solution and laboratory experimentation was included towards achieving these objectives.

It was also assumed that the minimum essentials of an engineering course should be given in order to prepare these selected soldiers as technical officers. The time limitation of three or four terms beyond the basic phase was set by higher authority. Since the duties of junior officers are normally restricted to operations and maintenance, only enough design work was included to give necessary drill in the theory, and to provide an integration of the knowledge gained in the other courses.

The original objectives of the ASTP have remained fundamentally unchanged, he continued but some modifications in the direction of providing a terminal point earlier in the schedule were necessitated, since it is no longer expected that graduates will be assigned directly to Officer Candidate School but rather to duty as technical noncommissioned officers. In particular, the revisions of the course outlines for the advanced phase are as follows:

In the Term IV course in calculus, emphasis is no longer given to differential equations. Extremely close coordination of the courses in mathematics and mechanics is requested especially in problems involving first and second moments. Close co-ordination is requested, also, between the course in electric and magnetic phenomena, and the course in electric measurements.

In Term V, the titles of the course in circuits and the course in applied mathematics have been changed so as to describe better the course content. It is expected that the course now called engineering applications of mathematics will be taught in the electrical engineering department and as a course in the application of mathematical procedures rather than a course in theoretical mathematics.

In Term VI, a course in telephone circuits and equipment has been added in order to provide a more effective training program for the trainees for whom Term VI is terminal. This course replaces the courses in transients and in distributed parameter circuits.

In Term VII, the addition of the topics of transients, trigger circuits, and pulse-shaping circuits to the course on communication networks has been made possible by the introduction of a portion of the material on communication networks into the telephone course in the previous Term. The course in radiation and propagation has been omitted and these topics have been included in the ultrahigh-frequency course. Since no course in transients is given, two contact hours have been added to the servomechanism course, in which transients are discussed as their applications arise.

Commander Adams then described the Navy V–12 program as it was planned and as it is unfolding. "The single and sole reason for the existence of the V–12 program is for the benefit of the Navy to win the war at the earliest possible moment," he declared. According to him, four basic principles underlie its organization and determine its developing policy. These are:

1. The Navy, having derived considerable advantage from the colleges and universities in the United States in the past, desires to conserve every possible value in higher education.

2. The Navy finds it desirable to disrupt normal academic procedures as little as possible.

3. No institution is to be penalized financially.

4. Word as to the developing policy will be sent to the administrators of the program as early as possible.

The matter of selecting and assigning the several thousand students who comprise the Navy College Training Program enrollment, Commander Adams declared, is the most challenging problem today. The screening tests which determine the eligibility of the student candidates for V–12 classification and possible advanced ratings are based on three considerations. First of all the student is asked his choice as to the upper level in which he wishes to go. Then an examination is made of his previous academic record, his qualifying examination, his record as an apprentice seaman, and a report of his aptitudes and attitude as expressed by his commanding officer. Final allocation is determined by the Navy's need

at the particular moment for trainees in the area of his choice and qualification.

The Navy doesn't want to confuse activity with achievement, Commander Adams continued, and it doesn't want to interfere with the academic standing of any of the participating institutions. For the most part, all those who have passed the qualifying examinations should be allowed to remain through the third term, but if the instructors believe that a student should not be continued, he should be separated. The road ahead is hard, and these boys must know, they must have the power that comes from certain knowledge. One does not get a second guess in naval operations of today. Some of the most important naval engagements in this war have been over in an hour or two, and the fate of half a dozen ships settled in that brief time.

During the open discussion which followed, many local problems of administration in both the ASTP and the V–12 programs as they existed at the various centers of training were explained, and those not requiring special military information were answered satisfactorily. The character of the discussions gave clear indication that the programs of specialized training were being administered effectively, and that the engineering colleges are doing a fine job of equipping a large personnel to assume more responsible roles in the technical phases of the present highly scientific modes of warfare.

Before the conference was turned over to consideration of the specialized training programs for the Army and Navy, Aram Boyajian (F '26) General Electric Company, Pittsfield, Mass., presented a paper on "The Cultural Training of the Engineer" (*AIEE Trans., Jan '44, pp 6–8*).

Principles and Performance Covered at Relaying Conference

Practical criteria for determining the type and location of faults requiring high-speed relaying to maintain transient system stability were outlined briefly by R. C. R. Schulze (M '31) Public Service Electric and Gas Company, Newark, N. J., in his paper, "Effect of Relay Operating Time on System Stability," presented at the conference on speed relaying held during the recent AIEE winter technical meeting.

Instability is likely to occur, he said, when the change in the relative phase position of an impaired machine and the remainder of the system exceeds an angle of 120 degrees. Sometimes delaying the relaying time may permit the machine to swing so far away from the system that it becomes impossible to pull it back into synchronism. In considering the various factors active in system stability he pointed out that anything diminishing the megawatts available for displacement decreases the need for speed relaying. "Any load connected directly to the generator bus will act as a cushion and will reduce the amount of phase-angle displacement, unless the fault is directly on the terminals of the generator itself, or the bus to which it is connected," he declared. Where turbine output is high, he recommended either a minimum of exposure between the generator terminals and wound equipment such as transformers or reactors, or a low-pressure slow-speed machine directly in parallel with the high-pressure unit to act as a brake. Other factors entering into the problem are system design and the amount of impedance to the fault. If the phase positions of the machines of a system change together, slower relays are possible, but, when one machine is likely to be affected more than the others, time is of greater import. A fault adjacent to a generator station must be cleared quickly whereas a fault on a distribution feeder probably can hang on indefinitely, he said.

Characterizing the method as a reliable and highly effective means of combating the stability problem, C. E. Parks (A '40) Public Service Company of Indiana, Indianapolis, described the performance of single-pole relaying and switching on a 50-mile 132-kv interconnecting line in his paper, "Influence of High-Speed Relays and Reclosing on Over-All System Performance." This scheme utilizes the fact that, since a large percentage of the faults on a modern transmission system are phase to ground, isolation of the faulted phase only will cause much less shock to the system involved in the fault than would be the case if the entire system were isolated. Synchronizing current will pass over the unfaulted phases during the time the faulted phase is isolated, and both systems will remain more stable for a longer period of time than they would with no interconnection at all.

The benefits of high-speed reclosing also have been demonstrated for the Public Service Company by another 73-mile section of 66-kv line, built on wood poles without static wire and protected by high-speed carrier-current relaying and three-pole reclosing. During 20 months of operation the line has been in fault 131 times. Of these faults 110 reclosed successfully while 8 were caused by permanent faults on the line. The customer complaint that formerly accompanied each one-minute interruption of service subsided when the reclosing was placed in service, Mr. Parks stated.

A selected amount of operating experience with short-circuits and faults on the lines and equipment of a representative central station was presented by H. R. Paxson (M '40) Philadelphia (Pa.) Electric Company, in his paper, "The Effect of Relay Operating Time on Damage to Equipment and Lines." Valuable statistical information on lines and equipment used on various voltage systems and fault records for diverse types of line construction were included.

The territory of the Philadelphia Electric Company described by Mr. Paxson, covers approximately 2200 square miles, and comprises distribution systems operating at 220 kv, 66 kv, 33 kv, 13.2 kv, and 2.4 kv. Data collected on the 220- and 66-kv systems, which are both equipped with high-speed relaying devices, between 1935 and 1942 showed that for the majority of interruptions involving aerial lines no conductor burn downs or serious line damage occurred. Mr. Paxson attributed this excellent record partially to the high-speed devices. On the 33-kv system where there is considerable time delay in relaying it was noted that although the number of interruptions was high the percentage of successful reclosures also was high. This led Mr. Paxson to suggest other factors besides relay settings which may influence the number of burn downs. He stated that the use of relatively large, bare conductors with wide spacings reduces the probability of burn downs since weatherproof covering on conductors tends to confine an arc to one spot on the conductor with consequent burn down. This theory was borne out by his data on the 13.2-kv system which is protected by slow relays and for which municipal ordinance requires weatherproof covering.

In analyzing the effects of time delay, Mr. Paxson reviewed specific faults cleared by slow relaying and by high-speed relaying. He mentioned two cases of frequency converters pulling out of step on the 66-kv system: one before and one after high-speed relaying had been installed. Extensive damage was entailed in the first case and was absent in the second. A bus fault on the 66-kv system before differential protection was installed was communicated to other equipment with an average outage of 17 minutes. After the installation of high-speed relaying, a circuit breaker exploded with no associated damage and another fault resulted in very little burning.

The discussion following the presentation of the papers stressed the benefit of relaying improvements in serving the customer but posed the question of whether it is always economically justified from the standpoint of furnishing more kilowatts at less cost.

One discusser stated that speed relaying should be confined to relaying out parallel lines. He added that the method was applied best in faults involving two interconnected load feeders and that for a cable fault in a substation no relaying seemed necessary at even so short a distance as a mile from the critical area.

E. L. Harder (M '41) chairman of the subcommittee on high-speed relaying, presided at the conference.

Turbogenerator Characteristics Discussed at January Meeting

Three basic characteristics of turbogenerators—ratio of generator rating to turbine rating, power-factor rating, and short-circuit ratio—were the subject of discussion at the conference on turbogenerator characteristics held January 25 during the AIEE winter technical meeting. The conference was attended by a large number of engineers representing users and manufacturers, with resultant valuable discussion that will aid the AIEE–ASME Joint Committee on Turbogenerators in its standardization project. M. S. Oldacre, chairman of the AIEE group of the Joint Committee, presided.

A report was presented by the AIEE group giving the results of questionnaires sent to about 95 members of the AIEE electrical machinery and power generation committees, Edison Electric Institute electric equipment committee and interested utilities. Replies were received from representatives of over 40 operating companies representing in excess of 15,000,000 kw of installed generating capacity. With the additional information presented during the discussion, the data now available are representative of over 18,000,000 kw of installed generating capacity, or in excess of half of the steam generating capacity of the United States.

The committee is concerned with units of 10,000-kw capacity and above, and for the present is confining its work to 3,600-rpm units, for which the ASME group has recommended ratings of 12,500, 20,000, 30,000,

40,000, and 60,000 kw. Each of these units will have a guaranteed maximum capacity of ten per cent above its nominal rating. In many cases in the recent past, units have been given a name-plate rating of 80 per cent of the maximum capability of the turbine and the generator has been given an 80 per cent power-factor rating. To develop full kilowatt capacity of the turbine, it has been necessary to operate the generator at unity power factor. This 80 per cent rating basis, or conversely the 25 per cent margin of turbine capacity above generator kilowatt name-plate rating, will be superseded by only a ten per cent margin if the ASME recommendations are adopted.

The two questions of most immediate concern are the power-factor rating of the generator, and the short-circuit ratio as an indication of the stability of the unit under steady-state and transient conditions.

The questionnaire and discussions emphasized that there has been a lack of proper co-ordination between the turbine and generator capabilities which in many cases resulted in the turbine-generator units being deficient in kilovar capability at the high loads with the present 80 per cent power-factor generators and 125 per cent maximum turbine rating; lack of co-ordination also existed in other parts of the plant, for example, in the capability of the boiler plant with that of the turbogenerator.

The manufacturer representatives in the AIEE group discussed the effect on the generator if some of its characteristics were changed, and pointed out that they were desirous of standardization for the progress that it would mean but that they had no preconceived program of characteristics that should be adopted for standardization purposes.

The conference was of considerable benefit, and from the information presented there and the discussion it has stimulated, the AIEE group is continuing its work so that it can recommend a standardized program. When the AIEE recommendations have been prepared and adopted, it is intended that they should be published jointly with the recommendations of the ASME as a complete report on turbogenerator standardization. (*M. S. Oldacre, chairman AIEE group, AIEE–ASME Joint Committee on Turbogenerators.*)

Standards and Performance Topics of Industrial-Control Conference

Proposed standards for, and performance of, industrial-control devices were the main topics for discussion at the conference on industrial control, held January 26, during the AIEE winter technical meeting. E. H. Alexander (M '43), General Electric Company, Schenectady, N. Y., presided.

(Left) R. T. Henry of the Buffalo, Niagara, and Eastern Power Corporation; J. E. Hobson of the Illinois Institute of Technology, C. M. Laffoon of the Westinghouse Electric and Manufacturing Company, J. E. Housley of the Aluminum Company of America, and M. D. Ross of the Westinghouse company, were photographed in the lobby of the Engineers' Building while attending the winter meeting

(Above) Chatting between sessions at the winter meeting are H. N. Muller, Jr., Westinghouse Electric and Manufacturing Company, G. E. Dana, New York State Electric and Gas Corporation, G. Steeb, Buffalo, Niagara and Eastern Power Corporation, J. R. Stover, New York State Corporation, and L. J. Audlin, Central New York Power Corporation

L. T. Rader (A '34) General Electric Company, Schenectady, N. Y., outlined the existing need of standards for industrial-control devices. In the opening lines of his paper he declared that until now there has been no subcommittee on industrial control, and for that reason many control problems of vital importance have remained undiscussed. Doctor Rader pointed out that, since the requirements of the different divisions of industrial control vary so widely, standards for these divisions may vary, and "the need definitely exists for somebody to set up some standards." He enumerated nine topics which he claimed should have specific standards. These were:

1. Specification of arc-interrupting ability of a-c contactors.
2. Definition of "inductive load" when associated with d-c interruption.
3. Allowable temperature rise of contactor tips.
4. Allowable temperature of coil insulation.
5. Current–time characteristics of overload relays.
6. Specifications to limit voltage surges caused by d-c switching.
7. An immediate overhauling of present standards to fit them to the low-power control circuits in electronic controls.
8. Allowable cooling-air temperatures for forced-convection resistors when the air ducts travel through various kinds of building material.
9. A reasonable ambient temperature for various applications, since ambient temperature affects coil and contact tip heating so critically.

As a substitution for the paper originally scheduled for presentation by E. H. Alexander, R. A. Andrews, Ward Leonard Electric Company, Mount Vernon, N. Y., introduced "Electronic Speed Regulation." Mr. Andrews stated that uses for speed regulation in industry are increasing steadily. He pointed out that an electronic speed regulator consists of three basic elements: a power detector, an amplifier, and a power unit.

At the conclusion of this paper E. H. Alexander offered the following comment:

"The electron tube is now, to the electrical engineer, just another tool added to his well-filled 'tool chest.' Often its choice for an application results in doing a better job than was ever done before."

P. L. Hoover (M '39) Case School of Applied Science, Cleveland, Ohio, offered an alternative to the designation Mr. Andrews gave the elements of a speed regulator. He said that in teaching he found it much more appropriate to substitute the terms measuring element, translator, and amplifier in place of those given by the author.

G. A. Moffett, General Electric Company, Schenectady, N. Y., spoke on "Overload Protective Devices for A-C Induction Motors." Mr. Moffett announced that, after a brief review of the occurrences within and about a motor subjected to overloads at and within the range of stalled conditions, he would offer three specific questions with the purpose of provoking discussion. He said that investigations have proved that practically all failures occur from one of these five causes:

1. Continuous overload caused by excessive load or by a low line voltage.

2. Equivalent of one caused by a duty cycle where rms current exceeds the motor rating or by a too frequent start-stop duty cycle.

3. Stalled rotor due to excessive load, causing the motor to fail to start—a condition which gives approximately 600 per cent rated current for an average d-c motor.

4. Stalled rotor due to single phasing of the power supply—a condition which gives about 86 per cent of the three-phase stalled current or about 500 per cent of rated full-load current of an average a-c motor.

5. Excessively high ambient temperatures. Standard general-purpose motors are designed to operate in a maximum occasional ambient temperature of 40 degrees centigrade, and, if fully loaded in a higher ambient, the motor will overheat.

Mr. Moffett stated that to protect a motor adequately an overload relay must give running protection and, in addition, be fast enough to remove the motor from the line within the allowable stalled time, with only 86 per cent of the three-phase locked-rotor motor current flowing in the relay. After this review the author presented the following questions:

"1. Should we continue to attempt to build relays having heating characteristics closely approximating those of the motors—relays that provide both running and stalled protection—or should we concentrate on a good, reliable, small, and inexpensive device that makes provision only for stalled protection?

"2. Assuming that present practice is to be followed, should we have one relay providing a single characteristic, or should there be more, say three, one designated as fast, one medium, and one slow, and if so, what should be the established trip time at 600 per cent relay rating?

"3. Should we continue present practice, or should the manufacturers provide ambient compensated relays for general-purpose applications?"

The final paper to be presented at this conference was "The Behavior of Rectifier Circuits Supplying Industrial-Control Devices" by E. E. Moyer and P. T. Chin (A '41), both of General Electric Company, Schenectady, N. Y. The subject matter was confined to inductive loads, such as the coils of relays and contactors, and field windings of rotating machines. A comparison was made between the behavior of a circuit comprising resistance and inductance in series when supplied from a source of pure direct current and when it was supplied from a rectifier. The authors had prepared a number of slides illustrating their subject. These included diagrams showing the rise of current in a circuit comprising resistance and inductance in series, wave forms of a half-wave rectifier, graphical presentation of the meaning of average and rms values of a current pulse, comparison of a battery-energized circuit with a half-wave "free-wheeling" type of rectifier circuit, analysis of a controlled-rectifier output-voltage wave into its component sine waves, and some others.

Co-operation Theme of Conference on Civic Affairs

Co-operation of AIEE with cognate technical societies, with other professional groups, and with civic bodies was discussed at the conference on civic affairs and co-operation with other organizations during the recent AIEE winter technical meeting. H. W. Bibber, vice-chairman of the technical program committee, presided.

The consensus of opinion was that co-operation should be handled by local groups with simple organization and on specific subjects, and that co-operation tended to break down when a superstructure was built to supervise it.

P. L. Alger (F '30) of General Electric Company, Schenectady, N. Y., past chairman of the technical program committee, suggested that each AIEE committee should survey its field of interest and follow through one certain aspect of co-operation with other societies. The co-operating societies should invite each other to meetings of mutual interest and exchange programs and papers.

Resistance and arc welding have increased tremendously with the war program, declared G. W. Garman (A '38) of General Electric Company, Schenectady, N. Y., member of the AIEE electric welding committee, who urged co-operation between AIEE and the American Welding Society in the publication of papers and Standards of mutual interest.

The Radio Technical Planning Board which now has about 12 sponsors was cited by H. M. Turner (M '20) of Yale University, New Haven, Conn., as an example of bringing engineers together for effective co-operation. He proposed an advisory organization of all electrical people to submit recommendations to Congress and to other groups (*EE, Dec '43, pp 557–8*).

The New York Section has held many meetings jointly with other societies, announced M. D. Hooven (M '30) of Public Service Electric and Gas Company, Newark, N. J., vice-chairman of that Section. Joint meetings are held with the Illuminating Engineering Society, and the communications group often meets in conjunction with IRE. He proposed national solidification of these joint groups.

C. W. Fick (F '39) of General Electric Company, Cleveland, Ohio, said that the Cleveland Engineering Society building serves as a bond among the 23 engineering societies in that city, and that the societies also have a common publication; he declared that a like situation existed in Cincinnati. Experience in Kansas City, however, indicated that joint interest and a common bulletin were not sufficient to keep a group together, according to V. P. Hessler (F '43) of the University of Kansas, Lawrence, chairman of the Kansas City Section, but that an important joint project was necessary. Co-operative work on a community scientific library has helped cement joint-group interests in Kansas City during the past year. He recommended publication of news of local joint activities in *Electrical Engineering* as a means of affording other local groups ideas on co-operation.

Past President D. C. Jackson (F '12), Massachusetts Institute of Technology, Cambridge, cautioned against permitting one organization to undertake the problem of guidance in the formation of a joint society, but advocated allowing the society to act as a center and a host without control. If engineers wish to take community action on any issues, they must have unity of action among themselves first, he declared, and suggested the ECPD canons of ethics as a means of unifying engineers when they join together to accomplish a common objective.

Such issues as the collective-bargaining battle being conducted by American Society of Civil Engineers should be tackled by all engineers as a group, and not by one society nor by the societies individually, said Vice-President C. W. Ricker (M '36), Tulane University, New Orleans, La. He recommended the holding of a national meeting of district leaders of the various societies to plan and foster co-operation. The AIEE board of directors has authorized appointment of a committee to study conditions affecting the securing of employment and compensation among electrical engineers with special reference to problems of collective bargaining and has requested that this committee collaborate with a corresponding committee of ASME. Details are given in a separate item.

The setting up of separate joint organizations to handle special problems rather than large general organizations to cover numerous issues was advocated by J. F. Fairman (F '35) of Consolidated Edison Company of New York, Inc. He cited Engineering Council for Professional Development which has been involved in the selection, guidance, and training of young engineers for 11 years as an example of a co-operative enterprise among engineering societies (*EE, Dec '43, pp 556–7*).

Past President D. C. Prince (F '26), General Electric Company, Schenectady, N. Y., recommended that the Sections committee and the technical program committee should organize programs with other societies, and that joint subcommittees of these organizations should be formed in the Sections to sponsor co-operation.

Joint Session on Generation, Transmission, and Distribution

Four papers featured the joint session on power generation and transmission and distribution January 24, during the recent AIEE winter technical meeting, two papers dealing with the effect of loads on a-c generators under steady-state and transient conditions, one concerned with lightning protection for rotating machines when connected directly to overhead lines, and one discussing the effect of kilovar supply on system design. A. C. Monteith, chairman of the committee on power generation, and H. E. Wulfing, chairman of the committee on power transmission and distribution, both presided.

Paper 44-15, "Regulation of A-C Genera-

tors With Suddenly Applied Loads," by E. L. Harder (M '41) and R. C. Cheek (A '42), both of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., concerns chiefly the sudden application of relatively large load to a-c generators with self-excitation. This has become a serious problem in connection with loads on shipboard. The paper gives very complete curves and discussion of the use of curves to estimate voltage drop and recovery under such operating conditions. There were two discussions on this paper, by G. E. Frost (A '41) General Electric Company, Washington, D. C., and F. V. Smith (M '38) Sargent and Lundy, Chicago, Ill.

The second paper, 42-12, "Steady-State Stability of Synchronous Machines As Affected by Voltage-Regulator Characteristics," by C. Concordia (M '37) General Electric Company, Schenectady, N. Y., deals with the steady-state application of torques to a-c machines and presents very complete formulas on the treatment of such a problem.

"Lighting Protection for Rotating Machines," paper 44-17, by G. D. McCann, Jr. (A '38); E. Beck (M '35); and L. A. Finzi (A '40); all of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.; discusses a number of different alternate schemes and the relative merits of these when a-c generators directly connected to overhead lines are to be protected, such lines being exposed to lightning surges. These schemes are applicable not only in power generating stations but also in industrial plants where the source of power comes in over exposed lines. This paper was discussed by W. J. Rudge, Jr. (M '39) General Electric Company, Pittsfield, Mass.; E. R. Whitehead (M '39) Duquesne Light Company, Pittsburgh, Pa.; and I. W. Gross (M '40) American Gas and Electric Service Corporation, New York.

The last paper, 44-23, "The Effect of Kilovar Supply on the Design of Systems for Load Growth," by T. W. Schroeder (A '37), J. W. Butler (M '38), and N. H. Meyers (A '41), all of General Electric Company, Schenectady, N. Y., is very timely, since quite often additional kilovar supply will permit existing systems to carry larger loads with very little use of strategic materials. Discussion on this paper was presented by R. G. Hooke (M '28) Public Service Electric and Gas Company, Newark, N. J.; J. G. Holm (M '29), Boston Port of Embarkation (Mass.); and B. M. Jones (F '42) Duquesne Light Company, Pittsburgh, Pa. (*A. C. Monteith, chairman, AIEE committee on power generation.*)

Standards Committee Adopts Two New Standards

Two Standards were approved at the Standards committee meeting of the AIEE winter technical meeting—AIEE Standard 31, "Capacitance Potential Devices and Outdoor Coupling Capacitors," and revision of AIEE Standard 45A, "Modification and Supplement to AIEE Standard 45." Considerable interest is being shown throughout the industry in standardization and simplification of electrical apparatus, and progress was reported concerning several active projects.

A subcommittee of the Standards committee is correlating with the American Society of Mechanical Engineers in the standardization of turbogenerator characteristics in sizes 10,000 kw and above and at this time is giving particular attention to 3,600-rpm units. This group jointly with the power generation committee sponsored a conference during the winter technical meeting and is now formulating tentative recommendations concerning standard electrical characteristics. When this work is completed, the results will be made available to the industry in a joint report with the ASME.

At the present time the wording in various Standards regarding general service conditions is not uniform. Another subcommittee is analyzing the various wordings and correlating them so that uniform terms and phraseology may be available for consideration by the individual technical committees when considering revisions of the various Standards. This group has formulated a tentative set of "Guiding Principles for the Specification of Service Conditions in Electrical Standards."

Work is being carried on actively in the standardization of cable terminal potheads, analyzing the requirements and correlating with the designs which are available. It is expected that this will result in a Standard similar to AIEE Standard 21, "Apparatus Bushings," which was approved in June 1942.

Last year one of the major activities of the Institute was the preparation of wartime Guides and reports. A total of 14 was prepared, and the industry demand for these so exceeded the expectations that for some time the supply of some has been exhausted. One of these, "Industrial Power Distribution Systems," is being reviewed and it is expected that it will be reissued in a few months.

With the advent of new high-temperature insulating materials and the requirements of the aircraft industry for extremely lightweight compact electric equipment, investigations are being conducted to determine temperature limits and ratings suitable to such applications. Conferences have been held, and every attempt is being made to establish conditions and values which ultimately may result in standards. Consideration is being given to sponsoring the formulation of a basic standard test code covering low-frequency impulse and d-c tests. (*J. R. North, chairman, AIEE Standards committee.*)

Safety Committee Outlines Activities for the Year

Outlining his conception of the nature, scope, and possible activities for the coming year of the AIEE committee on safety, W. R. Smith (F '30) chairman, opened the meeting of that committee held during the Institute's 1944 winter technical meeting. In his opinion the committee should be concerned with such subjects as will lead to its recognition as the foremost committee in the field of electrical safety from the technical standpoint.

Discussion of a possible need for the re-examination of the principles behind resuscitation from electric shock was stimulated by presentation of AIEE technical paper 44-22, "Study of Artificial Respiration on Anesthetized Men," by W. B. Kouwenhoven (F '34), D. R. Hooker, and J. A. York, all of The Johns Hopkins University, Baltimore, Md. (*Trans., Jan '44, pp 1–2*). C. F. Engel, assistant medical director, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., pointed out that though there were no unique symptoms attendant on electric shock, it was generally assumed that the effect produced was a paralysis of either the respiratory tract, the diaphragm, or the heart. However, Doctor Engel stated that he has suspected for some time that what actually occurs is similar to an exaggerated faint in that all the blood in the body rushes to the vessels of the abdomen. He said that pressure on the abdomen concomitant to the application of artificial respiration, especially in the pole-top method, may actually revive the victim by forcing the blood back to the vicinity of the heart and hence into circulation.

Several other examples which supported Doctor Engel's contention were supplied by those present. Doctor Kouwenhoven stated that abdominal pressure had been successful in most cases with dogs. E. W. Oesterreich (F '42) superintendent of distribution, Duquesne Light Company, Pittsburgh, Pa., and inaugurator of the pole-top method, mentioned a case in which a victim had been caught behind a bathtub and was revived by abdominal pressure applied in accordance with the pole-top technique. He added that in some cases no resuscitation was necessary when noninjurious falls followed the electric shock. Mr. Smith pointed out that the recognized importance of the time element in reviving victims might indicate that the circulation of the blood must be started rather than respiration alone. He announced the completion of a pamphlet of instructions on the pole-top technique by the accident prevention committee of the Edison Electric Institute. Copies may be obtained by request to the committee on safety or to the Edison Electric Institute, 420 Lexington Avenue, New York, N. Y.

Mr. Smith brought to the attention of the meeting the need for maintaining closer relations with the Student Branches in such things as supplying speakers upon request as well as in bringing the whole question of safety engineering before students. He remarked that engineering graduates appearing in industry were often woefully ignorant of even the rudiments of safety principles. In recommending a paper prepared by C. K. Drinker, professor of physiology, Harvard University, for the National Safety Congress in October 1943, "Evidence Pointing to the Need for a Broader View of Accidents Due to Electricity," Mr. Smith remarked that the seriousness of the low-voltage hazard was not evident in general from mortality statistics alone for the reason that the number of fatalities was not large. He emphasized the importance of efforts being made to give domestic, commercial, and industrial users a better understanding of the fundamentals involved and of the simple precautions that should be taken in the usage and maintenance of equipment, devices, and appurtenances. Mr. Smith announced that the proposal had been made to the committee on domestic and industrial applications that investigation be initiated on the hazards of leakage currents in regard to farm animals. W. B. Buchanan (M '32) Hydro-Electric Power Commission of Ontario, Toronto, head of a group which has already started such investigations, stated that his group was functioning well as a fact-

finding body but was experiencing difficulty in applying its data. He added that information already collected indicated that engineering for farms needs more individual attention than has been accorded it heretofore. Although individual losses of animals may seem numerically small, they represent a serious drain in farm economy. He suggested that perhaps the electrical codes need revising in reference to farm wiring where special conditions must be satisfied since the chief danger is to animals.

Mr. Smith called tten tion to evidences of the need for a better dissemination of authoritative information on the physiological conditions and first aid care of victims of electric shock which could be helpful to ambulance surgeons and other members of the medical profession who are called to attend such victims. Under consideration is the proposal to have an authoritative paper prepared for presentation, through the co-operation of the American Medical Association, at a meeting of that Association and published in its *Journal* and *Electrical Engineering*.

For its future publicity program the committee contemplates the preparation of material for publication in the news columns of *Electrical Engineering* and in this connection hopes to receive suggestions from readers about the type of item which will be most helpful to them. It also desires suggestions on any papers that the committee could sponsor, either directly or jointly with the appropriate technical committee.

Loading and Protection Discussed at Transformer Session

Two papers presented at the session on transformers, January 28, 1944, during the recent AIEE winter technical meeting, were on the subject of overloading and protection of transformers. One paper by W. C. Sealey (M '38) of Milwaukee, Wis., and J. B. Hodtum (M '26) of Pittsburgh, Pa., both with Allis-Chalmers Manufacturing Company, showed means for determining the overload capacity in accordance with the information supplied in previous reports, such as the American Standard *C* 57, "Guide for Operation of Transformers," and the AIEE "Interim Report on Guides for Overloading Transformers and Voltage Regulators" (*AIEE Trans., Sept '42, pp 692–4*). Temperature–time charts were presented, and a method of using them was described. Several of those discussing the paper thought that these curves were in such form that they could be understood easily and would be very useful as a guide in loading transformers.

A paper by V. M. Montsinger (F '29) and G. Camilli (F '43) of the General Electric Company, Pittsfield, Mass., described a new protective arrangement for transformers under overload conditions. This device is arranged to allow for the short-time heavy loads that are permissible as well as the lower loads for long-time intervals. A description was given of the operating principles of the device and also a comparison of the results obtained by this device with the recommendations of the transformer operating guides.

A paper by P. L. Bellaschi (F '40) and Paul Evans, Jr. (A '38) of the Westinghouse Electric and Manufacturing Company, Sharon, Pa., gave the results of research on the effect of altitude on impulse and 60-cycle strength of electrical apparatus. The report covered an extensive investigation under carefully controlled conditions, and the information will be of great value in rating apparatus under high-altitude conditions and in determining the stability of standard apparatus for operation under high-altitude conditions.

The other paper presented at the meeting, "Asymmetrical Loading of Three-Phase Three-Winding Transformer Banks," by P. K. Denissov of the Academy of Science of the Union of Soviet Socialist Republics, described the method of calculating the loading requirements of transformers which would supply single-phase traction load as well as three-phase industrial load. This is seemingly a condition that is encountered in Russia. The most economical transformer installation results when different capacities are provided for the different phases, and this paper shows a method of determining the requirements. (*M. S. Oldacre, chairman, AIEE transformer subcommittee.*)

Teaching Aids at AIEE Meeting for Navy V–12 Training Program

Two special educational sessions at the AIEE winter technical meeting were devoted to aiding the teaching staffs of those engineering colleges throughout the country in which the Navy V–12 specialized training program is being conducted. A representative from each of the colleges so commissioned was invited to attend these co-operative meetings, sponsored jointly by the AIEE committee on education, Robin Beach (F '35) chairman, and the training division of the Bureau of Naval Personnel.

One of these sessions, on Thursday afternoon, January 27, was devoted to an inspection tour through the Brooklyn (N. Y.) Navy Yard. Under the guidance of Navy officers, the specially invited group of 40 electrical engineering teachers examined ships of the destroyer and cruiser class from stem to stern. The compactness and tremendous power of the propulsion machinery was pointed out to them, and they also studied the electrical machinery and control devices.

As a follow-up to the field trip, Captain H. G. Rickover, chief of the electrical section, Bureau of Ships, United States Navy, Washington, D. C., addressed the same group who had inspected the Navy Yard on the previous day at a closed session on Friday morning, January 28. In an informal talk he discussed the subject of most modern design of generating and distributing systems for electric power on shipboard. He explained the manner of segregating and locating generating units, switchboard control centers, and distribution feeders in order to provide maximum reliability in the operation of Naval craft.

Captain Rickover also delivered an address dealing with the subject of electricity on shipboard at an open session Friday evening. He explained the subject of damage to Naval craft from shock resulting from explosions of mines, depth bombs, torpedoes, and aircraft attack. While lecturing he illustrated his explanations with slides of testing machines which have been developed for simulating shock conditions, and by means of which electrical machinery, control units, instruments, and switchboards can be designed now to meet more effectively the rigorous requirements of battle conditions. Another phase of his address treated the subject of rehabilitation of submerged electrical machinery in location. His illustrations showed the dismantling, rewinding, dynamic balancing, and reassembling of large electrical machines in the holds of Navy ships which had been submerged for months. (*Robin Beach, chairman, AIEE committee on Education.*)

Year's Work on Insulating Oils and Cable Saturants Reviewed

A comprehensive report of work done during the past year on the Engineering Foundation–AIEE Research Project on Insulating Oils and Cable Saturants at the Massachusetts Institute of Technology was the subject of a meeting of the AIEE advisory committee and the research workers. The meeting was held in New York on January 27. A brief outline of this project is given in a previous issue (*EE, Jan. '44, p. 38*).

The recent report is of special interest as several problems are covered. Studies have been made on the effect upon the electrical stability of oil of additions such as a number of inhibitors and carbon black. The problem is complex and more work will be necessary, but the results obtained give some interesting insight into the characteristics of oil deterioration.

Investigations covering a temperature range from 85 to 145 degrees centigrade indicated that the effect of temperature upon the electrical stability of oils may be quite different under limited oxidation with relatively small amounts of oxygen from what it is under continuous oxidation with unlimited supply of oxygen.

Because of war conditions, this research project was stopped. The recent report is being distributed to a list of people, and requests for free copies can be made to J. C. Balsbaugh, Massachusetts Institute of Technology, Cambridge, Mass., or to Herman Halperin, Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill. (*Herman Halperin, chairman, Engineering Foundation–AIEE Research Project on Insulating Oils and Cable Saturants.*)

W. K. Boice and L. G. Levoy of the General Electric Company, Schenectady, N.Y., with the 400-cycle, a-c aircraft generator which they described at the winter meeting

Major-General Roger B. Colton, who addressed a joint AIEE–IRE evening session of the AIEE winter technical meeting on enemy army communications equipment, is explaining a piece of captured German airborne radio equipment displayed by the Signal Corps during the meeting to two WACS

Colton Describes Enemy Communications Equipment

Enemy army communications equipment was the subject of an address by Major General Roger B. Colton, chief, engineering and technical service, Signal Corps, United States Army, before a joint AIEE–IRE evening session of the AIEE winter technical meeting, January 27, in New York, N. Y.

Indicative of the importance of communications equipment in this war was the general's statement that "the largest annual appropriation for the Signal Service of the Army during World War I was $83,000,000 while during the fiscal year ending June 30, 1943, the appropriation amounted to more than $5,500,000,000—66 times as large." The speaker said that, of the 200 principal items now being delivered to the Signal Corps, 115 of them were developed and standardized since July 1941.

Speaking of enemy army communications equipment, he declared that the German is the best and the Japanese the poorest. The German airborne electrical design is sound but not advanced. The mechanical design, incorporating die castings, and specially designed parts, is of excellent quality, and the cabling is neat. Their equipment is standardized to allow for mass production. In some instances chassis are only partly filled with parts, which indicated that the same chassis is used for other installations. Tubes also have been standardized.

A great deal of the Japanese airborne equipment is obsolete in design and construction from our viewpoint. Wiring in these sets is neatly carried throughout, and a number of points of design resembling American technique have been adapted rather than copied.

German ground components are well built and throughly designed, and all parts are marked with terminal numbers to facilitate easy replacement. Dials are well machined and accurate, and wiring is small and neatly cabled. Japanese ground parts are of obsolete design and in some cases very inferior to American parts. Japanese coil forms are in general very poor. Usually wooden or molded-mud-insulation coils are used. Jap transformers are usually unpotted, and there is no evidence of weatherproofing. Jap crystals and holders are of good design, however, and several Jap holders examined have been very accurately molded, and the crystals accurately ground.

Major General Colton who illustrated his talk by photographic slides of captured enemy equipment stated that this was the first complete discussion of enemy apparatus made public by the Signal Corps.

Special Committee Authorized to Study Employment Conditions

Among the important actions taken by the AIEE board of directors during the recent winter technical meeting was the authorization of a special committee to "study broadly the conditions affecting security of employment and compensation among electrical engineers, with special reference to problems of collective bargaining." The committee is requested to collaborate with a corresponding committee of the American Society of Mechanical Engineers if that society establishes such a committee. Power was given to employ a labor relations adviser, and an appropriation of $1,000 was set aside for the use of the committee. Personnel of the committee has not yet been appointed.

Many engineers, particularly those in industrial plants, have found themselves under pressure to join employees' unions for collective-bargaining purposes. Protestations that they are professional personnel and therefore incorrectly classified with nonprofessional or subprofessional union groups are usually of no avail. The net result has been that many engineers, particularly the younger men entering upon their professional careers in subordinate positions, have been faced with the necessity of either joining unions dominated by nonprofessional people or giving up their employment.

These men have looked to their professional societies for help in this perplexing and trying problem, and one of the Founder Societies, the American Society of Civil Engineers, already has taken positive action by establishing machinery for the organization of collective-bargaining units by its local sections (*EE, Jan '44, p 34*). Formation of such groups, which will be recognized legally as the collective-bargaining agents exclusively for professional engineers, was considered by the society to be the only alternative to bowing before the authority vested in unions of a subprofessional or nonprofessional level. Other societies also are studying the problem to determine what if any action should be taken.

It is expected that the new AIEE committee, after thorough study of all factors involved, will formulate a recommended basic policy that will (1) assist in clarifying the relationship of electrical-engineering personnel to collective-bargaining units and (2) point to any action that can appropriately be taken by AIEE to assist its members who find themselves in this paradoxical situation.

Committee Reports on Voltage Transients in Arc-Furnace Circuits

A progress report by the subcommittee on voltage transients in arc-furnace circuits was submitted orally by E. R. Whitehead (M '39) Duquesne Light Company, Pittsburgh, Pa., at the meeting of the committee on electrochemistry and electrometallurgy, January 27, during the recent AIEE winter technical meeting. This report will be submitted officially after certain changes requested by the subcommittee have been made and will be published as soon as it has been approved. An excellent summary of a considerable number of tests made at different furnace installations and a tabulation of results obtained have been made by the data group of the subcommittee.

According to the report of the subcommittee on dry-type rectifiers, considerable progress already has been made in studying the possibilities of standardizing the nomenclature and symbols used. The report presented by M. F. Skinker (F '34) of International Telephone and Radio Manufacturing Corporation, East Newark, N. J., chairman of the subcommittee, indicated that a great deal more work needs to be done in what is a relatively new field.

Plans for obtaining a number of papers for the next session were discussed. It is expected that papers on induction heating, dry-type rectifiers, and other subjects within the scope of the committee will be obtained. (*C. C. Lovy, chairman, AIEE committee on electrochemistry and electrometallurgy.*)

Sections Committee Meets During Winter Technical Meeting

Allocation of unassigned territory in Arkansas to the Memphis–Tulsa and North Texas Sections was approved and recommended to the board of directors at a meeting of the Sections committee January 24

during the recent AIEE winter technical meeting. President N. E. Funk was present for a portion of the meeting and added some excellent ideas to the discussion. Chairman G. W. Bower presided at the meeting which was attended by 22 members.

This assignment of territory in Arkansas completes the allocation of all unassigned territories in the continental United States. The removal of the Midwestern Canada Section from the active list of Sections of the Institute was approved and recommended to the board. This Section has disbanded. The removal of this Section leaves the Provinces of Manitoba, Saskatchewan, and Alberta in District 10 of Canada as unassigned territory.

The delegates' meeting at the AIEE national technical meeting in St. Louis was discussed, and tentative plans provide for a meeting of delegates and also clinics to furnish discussions by the delegates of Section operation and management. This plan is similar to the one used in Cleveland last year with the exception that some novel changes in the program are being planned.

The development of technical groups within the Sections was discussed in detail. Chairman Bower reported the distribution to all Sections of a new folder on technical groups and told of the committee's progress in encouraging the formation of these groups.

Among the other items discussed were:

Development of additional sub-Sections; the plan of a simplified yearly report from each Section chairman on the year's activities of the Section; the plan of sending a Section committee letter during July of each year to the new Section chairman and secretaries, recommending some outstanding features of Section operation and management for their consideration; the use of identification cards or badges at Section meetings; a suggested publicity display during the delegates' meeting at St. Louis; co-operation with the Student Branch and educational committee; a plan of activity on civic affairs; preparation of a proposed manual on Section operation and management.

(*A. C. Muir, secretary, AIEE Sections committee.*)

Lighting Progress and Seeing Discussed at Conference

Recent progress of light sources and the mechanism of seeing were, respectively, the general subjects of two demonstration addresses at the conference on lighting held during the recent AIEE winter technical meeting. W. C. Kalb (F '40) chairman of the AIEE committee on production and application of light, presided.

In the first address, Preston S. Millar (A '03, M '13), president, Electrical Testing Laboratories, Inc., New York, discussed in some detail the improvements achieved in various types of light sources during recent years, demonstrating much of the improved equipment on the platform. His address is scheduled for publication in an early issue.

Declaring that not enough has been said about the reception and utilization of light by seeing organs, S. G. Hibben (A '34), director of applied lighting, Westinghouse Electric and Manufacturing Co., Bloomfield, N. J., pointed out that eyes have evolved as well as the producers of illumination. By a series of slides he showed the structure of the eyes in various levels of animal life, illustrating the evolution to more efficient seeing organs in the higher forms of life. By means of special equipment, he demonstrated the performance of the human eye under various conditions, and also illustrated the effects of defective eyesight. Mr. Hibben's address was supplemented by two motion pictures.

Australian Engineers Exchange Privileges With AIEE

An invitation from the Institution of Engineers, Australia, to AIEE members on service in Australia to accept the privileges of attending meetings, receiving publications, and using the reference libraries of the Institution was accepted by the AIEE board of directors at its meeting January 27. The board voted to extend its thanks for the proffered hospitality and to offer similar privileges to members of the Australian Institution serving in or passing through the United States.

The Institution of Engineers, Australia, which has its headquarters in Sydney, NSW, was founded in 1919 by the amalgamation of various state engineering associations and the Electrical Association of Australia. Divisional headquarters of the Institution exist in the capitals of each of the states of the Commonwealth of Australia as well as in Newcastle, NSW. Regular general meetings at which papers are presented are held by the Institution's divisions.

DISTRICT • • • • •

District 10 Executive Committee Meets in Montreal

Membership progress throughout the District and co-operation with the Engineering Institute of Canada and the Canadian Engineers' Council were discussed by members of the executive committee of the Canada District at a meeting held in Montreal, Que., January 17, 1944, at which W. J. Gilson, AIEE vice-president for the District presided.

Mr. Gilson outlined the background and present status of the Canadian Engineers' Council which held an organizational meeting in Montreal, Que., December 11, 1943, with representation from all the engineering bodies in Canada. With organization still in progress, Mr. Gilson proposed to submit a questionnaire to all Canadian AIEE members summarizing the development of the council and aiming at a definition of the members' opinion of the part the AIEE should take in the new council. The AIEE's relationship with the Engineering Institute of Canada in regard to its position and purpose as a national part of an international technical society was discussed at length, but no decision was reached.

An increase in membership was reported by Thomas Ingledow (M '41) for the Vancouver Section and by Frederick Krug (F '36) and D. M. Farnham (M '42) for the Montreal Section. F. C. Barnes (A '30) reported that attendance at meetings of the Toronto Section was well above average.

The Toronto Section reported very successful joint meetings with the Engineering Institute of Canada, the Institute of Radio Engineers, the Meteorological Society, and the Royal Canadian Institute. The Montreal Section has held two well-attended joint meetings.

Future AIEE Meetings

North Eastern District Meeting
Boston, Mass., April 19–20, 1944

Summer Technical Meeting
St. Louis, Mo., June 26–30, 1944

Pacific Coast Technical Meeting
Los Angeles, Calif., Aug. 29–Sept. 1, 1944

In a general discussion of Section procedure Mr. Ingledow recommended a question meeting which has been successfully introduced in the Vancouver Section. Members are asked to submit questions regarding problems on which they desire the opinion of experts, and the meeting is given over to consideration of the questions received. The Toronto Section has designated a committee to investigate the value of the use of badges by the members.

A letter was received by the vice-president from W. P. Dobson (M '19) of the Standards committee requesting that the District executive committee formulate a plan whereby draft standards might be circulated among Canadian AIEE members and their comments collected for the benefit of the Standards committee. As this would involve a classification of the members according to their specializations, it was moved by Mr. Ingledow and seconded by Mr. Farnham that the letter from Mr. Dobson be forwarded to the Sections and suggestions on a feasible course of action collected from them.

SECTION • • • • •

Milwaukee Section Membership Shows Steady Increase Since 1939

Contrary to a statement recently appearing in *Electrical Engineering* (Jan. '44, p. 25) the membership of the AIEE Milwaukee Section has not declined. Rather it has increased steadily from 270 members in 1939 to 358 as of November 1943.

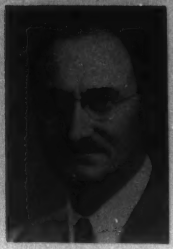
The erroneous statement appeared in a report of a meeting of the Great Lakes District executive committee at which membership problems were discussed in detail. The officers were concerned with the difficulties in maintaining the rate of growth established during the last five years in the face of circumstances beyond their control, such as the great flow of members into military service at the present time and the small influx of recent engineering graduates into industry. The committee was anticipating a probable decline in new-membership possibilities rather than reporting and discussing an actual decline in membership enrollment.

PERSONAL • • • •

Arthur Henry Kehoe (A '12, F '25) vice-president in charge of construction and shops, Consolidated Edison Company of New York (N. Y.), Inc., has been awarded the 1943 Lamme Medal "for pioneer work

R. W. Warner

M. S. Coover



C. A. Powel

A. H. Kehoe

in the development of alternating current networks and associated apparatus for power distribution." Mr. Kehoe was born in Bennington, Vt., February 18, 1889, and was graduated from the University of Vermont with the degree of bachelor of science in electrical engineering in 1911. He has been associated with the Consolidated Edison System Companies since 1911 when he entered the meter department of the United Electric Light and Power Company, New York. From 1914 to 1919 he was distribution engineer and in 1919 became superintendent of the transmission and distribution department. In 1921 he was made electrical engineer and in 1932 was appointed vice-president of the company. At present he is also a member of the board of directors of the New York and Queens Electric Light and Power Company, the New York Steam Corporation, and the Consolidated Telegraph and Electrical Subway Company. Mr. Kehoe served as president of the Edison Electric Institute from 1933 to 1939 and as president of the New York Electrical Society from 1936 to 1938 and is a former member of the board of the National Fire Protection Association. He is a member of Phi Beta Kappa and author of a number of technical papers. Mr. Kehoe has served on many AIEE committees including: electrical machinery, 1924–29; power transmission and distribution, 1924–29; board of examiners, 1927–31; power generation, 1928–29; Standards, 1935–42; and the Lamme Medal, 1937–40; and on the Standards council of the American Standards Association.

C. A. Powel Nominated for AIEE President

Charles Alfred Powel (M '20, F '41) manager, headquarters engineering departments, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been nominated to serve as president of the AIEE for the 1944–45 term. Mr. Powel, who was born July 30, 1884, in Rouen, France, of Welsh parents, was graduated from the Institute of Technology of Canton Bern, Switzerland in 1905 and was naturalized in the United States in 1930. He was employed in the application engineering department of Brown, Boveri and Company, Baden, Switzerland, from 1905 until 1911 when he was sent to Japan as resident engineer for that company. After the outbreak of World War I, he returned to England in 1915 and was connected with the Civil Branch of the British Ordnance Department, first at Woolwich Arsenal, and later in the United States with the British War Mission from 1915 to 1919. In 1919 he joined the Westinghouse company as engineer in the central station section of the general engineering department. He was appointed manager of the central station engineering department in 1935 and manager of the industry engineering department in 1938. He became manager of the headquarters engineering departments in 1940. Among the many AIEE committees of which Mr. Powel has been a member are: power generation, 1933–38; applications to marine work, 1936–40; electric welding, 1937–41; electrochemistry and electrometallurgy, 1939–40; constitution and bylaws, 1940–44; Charles LeGeyt Fortescue Fellowship, 1939–41–43 (chairman 1939–41); Lamme Medal, 1939–42; Standards, 1939–44; education, 1942–44; Edison Medal, 1943–48. He served as AIEE director for 1936–40 and vice-president from the Middle Eastern District (2) for 1942–43. He is the author of a number of papers.

Warner, Coover, Fairman, Henry, and Carpenter Are Nominated for Vice-Presidents

Robert W. Warner (M '28, F '39) professor and head of the department of electrical engineering, University of Texas, Austin, has been nominated AIEE vice-president for the South West District (7). Professor Warner who was born in Freeport, Ill., August 20, 1889, received the degree of bachelor of arts from Washburn College in 1911 and from the University of Kansas the degrees of bachelor of science in electrical engineering in 1918 and of electrical engineer in 1928. In 1918 he was connected with the Ordnance Department of the United States Army and in 1919 was junior engineer with H. L. Doherty and Company, Denver, Colo. From 1919 to 1921 he was assistant to the chief engineer of the Topeka (Kans.) Edison Company. He taught electrical engineering at the University of Kansas, Lawrence, in 1921 and 1922 and at the University of Wisconsin, Madison, in 1922 and 1923. After a period with the General Electric Company, Schenectady, N. Y., as engineer in the switchboard department in 1923 and 1924, he was employed by the Kansas City (Mo.) Power and Light Company as automatic substation engineer. Returning to the University of Kansas in 1928, he was appointed assistant professor of electrical engineering, in 1929 associate professor, and in 1933 professor of electrical engineering. In 1935 he was visiting professor at Massachusetts Institute of Technology, Cambridge, and in 1936 was appointed head of the department of electrical engineering at the University of Kansas. In 1938 he became professor and head of the department of electrical engineering at the University of Texas. His AIEE committee memberships include: the committee on education for 1939–40; and the standards committee for 1941–42. Professor Warner was District secretary for 1930–33; Section chairman for 1933–34 and for 1941–42. In 1934–35 he served as Student Branch Counsellor. He has represented AIEE on a committee of the American Standards Association. He is a member of the Society for the Promotion of Engineering Education.

Mervin S. Coover (A '16, M '32, F '42) professor and head of department of electrical engineering, Iowa State College, Ames, has been nominated AIEE vice-president for the Great Lakes District (5). Professor Coover was born in Shippensburg, Pa., on December 9, 1890, and was graduated from Rensselaer Polytechnic Institute with the degree of electrical engineer in 1914. In 1914 and 1915 he was student engineer with the New York Central Railroad and in 1915 joined the Montana Power Company, Three Forks, as an assistant engineer. In 1917 he was employed by the United Water Power and Light Company, Hutchinson, Kans., as electrician and by the Wilson Grinding Machine Company, Wichita, Kans., as design engineer. After service in the United States Army, he joined the faculty of the University of Colorado, Boulder, as instructor in 1919. He became assistant professor in 1920, associate professor in 1922, and was made professor in 1930. In 1935 he was appointed professor and head of the department of electrical engineering at Iowa State College. Since 1942 he has been assistant regional co-ordinator of the Engineering Science and Management Defense Training program. Professor Coover has outlined courses of instruction in production, transportation, and personnel management and he is the author of a number of articles, pamphlets, and textbooks. He has acted as consultant on special problems for the General Electric Company, the City of Denver, and the Public Service Company of

J. F. Fairman

R. T. Henry

P. L. Alger

C. B. Carpenter

Colorado. He was a member of the AIEE board of directors from 1940 to 1944 and has served on the following committees: automatic stations, 1927–29; Sections, 1937–43 (chairman 1940–42); education 1937–43; research, 1937–40; planning and co-ordination, 1940–42; and the Edison Medal, 1941–43. He was District secretary from 1929 to 1931. In 1938 he received the John Dunlap Memorial award of the Iowa Engineering Society of which he is a member. He is also a member of the Society for the Promotion of Engineering Education, Tau Beta Pi, Eta Kappa Nu, and Sigma Tau.

Charles Benjamin Carpenter (A '23, M '34) assistant chief engineer, general engineering department, Pacific Telephone and Telegraph Company, Portland, Oreg., has been nominated for AIEE vice-president for the North West District (9). Born in Urbana, Ill., October 27, 1900, Mr. Carpenter was graduated from the State College of Washington with the degree of bachelor of science in electrical engineering in 1922 and from Stanford University with the degree of electrical engineer in 1923. He was employed as electrical draftsman by the Portland (Oreg.) Electric Power Company from 1923 to 1926. Entering the employ of the Washington Water Power Company, Spokane, in 1926, he was assistant to the engineer in charge of electrical design of the Chelan Power Project, and field electrical engineer until in 1929 he joined the Pacific Telephone and Telegraph Company, Seattle, as engineer in the chief engineer's department. After a few months in 1933 as technical man for the Home Telephone and Telegraph Company, Spokane, he was placed on the staff of the outside plant and transmission engineering department for the Oregon area of the Pacific Telephone and Telegraph Company. In 1941 he was appointed assistant chief engineer. Mr. Carpenter served on the AIEE committee on communications for 1938–41. He was Section secretary for 1931–32 and for 1937–38, and chairman for 1938–39. He was vice-president of the Professional Engineers of Oregon in 1941. He is a member of Tau Beta Pi, Sigma Tau, and Sigma Xi.

James Ferdinand Fairman (A '20, M '27, F '35) assistant vice-president, Consolidated Edison Company of New York (N. Y.), Inc., has been nominated AIEE vice-president for the New York City District (3). Born in Big Rapids, Mich., April 8, 1896, Mr. Fairman received from the University of Michigan the degrees of bachelor of science in electrical engineering in 1918 and master of science in 1921. After taking the graduate student course at the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., he continued at the University of Michigan, Ann Arbor, as instructor in electrical engineering from 1919 to 1922, and in 1922 was made assistant professor. In 1925 he joined the Brooklyn (N. Y.) Edison Company as assistant outside plant engineer and was made outside plant engineer and assistant electrical engineer in 1926 and electrical engineer in 1932. In 1937 he became electrical engineer for the Consolidated Edison Company and in 1941 was appointed assistant vice-president for design, inventory, purchasing, and stores. Mr. Fairman has served on many AIEE committees including: safety codes, 1931–34; general power applications, 1934–36; electrical machinery, 1936–37; the board of examiners, 1941–43; and the committee on education, 1941–42. Since 1938 he has been an AIEE representative on the Engineers' Council for Professional Development. He has been active in Section affairs, holding the Section offices of secretary for 1937–38 and chairman for 1940–41; as well as that of District secretary for 1937–38. Mr. Fairman served on the electrical equipment committee of the Edison Electric Institute and is president of the New York State Society of Professional Engineers. He is a member of Sigma Xi, Tau Beta Pi, and is a trustee of the Flatbush Savings Bank.

Raymond T. Henry (A '24, M '29, F '33) assistant chief electrical engineer, engineering department, Buffalo (N. Y.), Niagara and Eastern Power Company, has been nominated for AIEE vice-president for the North Eastern District (1). He was born November 17, 1889, in Stronghurst, Ill. In 1907 he attended the engineering school of the General Electric Company, Lynn, Mass., and in 1908 was employed as a draftsman by that company. As a draftsman he entered the employ of the Niagara Falls (N. Y.) Hydraulic Power and Manufacturing Company in 1909. He worked for the Hooker Electrochemical Company, Niagara Falls, as assistant electrical engineer in 1912 and for the Edison Illuminating Company, Detroit, Mich., in 1913. From 1914 to 1918 he was assistant superintendent in the Niagara Electric Service Corporation, Niagara Falls. Joining the Niagara Falls Power Company in 1918 as assistant electrical engineer, he became electrical engineer in charge of design in 1929 for the Buffalo, Niagara and Eastern Power Corporation, when the latter absorbed the Niagara Falls Power Company. Mr. Henry was awarded the AIEE national prize for the best paper in engineering practice for 1934 as co-author of the paper, "Fundamentals of Design of Electrical Energy Delivery Systems." He served as chairman of the Niagara Frontier Section for 1929–30. His other AIEE activities include membership on the protective devices committee for 1931–34 and for 1939–43 (chairman 1932–34); the standards committee, 1936–43 (chairman 1940–42); the committee on planning and co-ordination, 1940–42; and current service as AIEE representative on the Standards Council of the American Standards Association for 1941–43. He has been chairman of the Edison Electric Institute committee on electrical equipment for 1942–44. Mr. Henry was a member of the National Electrical Manufacturers Association's joint committee on oil circuit breakers.

Alger, McHenry, Quarles, Nominated for Directorships

Philip Langdon Alger (A '17, M '22, F '30) assistant to the vice-president in charge of design, has been nominated to serve on the AIEE board of directors. Born in Washington, D. C., January 27, 1894, Mr. Alger received the degree of bachelor of science from St. John's College in 1912 and from Massachusetts Institute of Technology in 1915. In 1920 he received the degree of master of science from Union College. He was laboratory assistant at Massachusetts Institute of Technology from 1915 until he entered the United States Army. In 1919 he was employed by the General Electric Company, Schenectady, N. Y., in the induction-motor engineering department and in 1923 was transferred to the a-c engineering department of which he was made assistant engineer in 1927. He was appointed assistant to the vice-president in 1929. He has served on the following AIEE committees: electrical machinery, 1926–32 (chairman 1929–32) and in 1942; Lamme Medal, 1932–35; Standards, 1932, 1942–44; planning and co-ordination, 1941–43; technical program, 1941–44 (chairman 1941–43). Mr. Alger is the author of several technical papers and a member of the American Society of Mechanical Engineers, the American Mathematical Society, the Army Ordnance Association, the Society

M. J. McHenry

D. A. Quarles

for the Promotion of Engineering Education, the American Association for the Advancement of Science, the Reserve Officers Association, the Newcomen Society, the American Legion, and the National Municipal League. In 1938 he was one of the United States delegates to the plenary meeting of the International Electrotechnical Commission at Torquay, England.

Morris James McHenry (A '11, M '20) director of sales promotion, Hydro-Electric Power Commission, Toronto, Ont., has been nominated to serve on the AIEE board of directors. Born in Catasauqua, Pa., August 8, 1888, he was graduated from McGill University with the degree of bachelor of science in 1910. From 1910 to 1912 he was engaged in the design of hydroelectric power stations with Smith, Kerry, and Chase, Consulting Engineers, Toronto. He joined the Canadian General Electric Company, Toronto, as sales engineer in 1912 and became assistant manager of the Toronto district office in 1916. From 1918 to 1924 he was manager and secretary-treasurer of the Walkerville (Ont.) Hydro-Electric System. He was made manager of the Ferranti Electric Company, Ltd., Toronto, in 1924 and manager of the United States sales department of the Canadian General Electric Company in 1926. In 1930 he was appointed district manager for Ontario, and in 1938 director of sales promotion for the Hydro-Electric Power Commision. He served as vice-president of the Institute for 1937–38 and has been a member of the committee on general power applications, 1920–22, 1937–38; and the committee on industrial power applications, 1938–43. Mr. McHenry is the 1943–44 chairman of the committee on transfers of which he has been a member since 1941. He was chairman of the Toronto Section for 1935–36. He is a member of the Association of Professional Engineers of Ontario, the Electric Club of Toronto, and the Electric Service League of Toronto.

Donald Aubry Quarles (A '23, M '29, F '41) director of transmission development, Bell Telephone Laboratories, Inc., New York, N. Y., has been nominated to serve on the AIEE board of directors. Mr. Quarles was born July 30, 1894, in Van Buren, Ark., and was graduated from Yale University with the degree of bachelor of arts in 1916. He served as captain in the United States Army during World War I and in 1919 entered the engineering department of the Western Electric Company, New York. When this department was incorporated into Bell Laboratories in 1925 he continued with the new organization. From 1919 to 1924 he worked as engineer and supervisor on transmission engineering research and in 1924 was made apparatus inspection engineer. Transferred to the outside plant development department, he was named plant system engineer in 1928 and was put in charge of the department as assistant director of apparatus development in 1929. In 1935 he was titled outside plant development director and in 1940 became director of transmission development. Mr. Quarles served as secretary of the New York Section for 1939–40 and as Section chairman for 1941–42. He is a member of the American Physical Society, Phi Beta Kappa, and Sigma Xi.

W. I. Slichter Renominated for AIEE Treasurer

W. I. Slichter (A '00, M '03, F '12) professor emeritus of electrical engineering, Columbia University, New York, N. Y., has been renominated for the office of AIEE treasurer which he has held since 1930. Professor Slichter was born in St. Paul, Minn, May 7, 1873, and was graduated from Columbia University with the degree of electrical engineer in 1896. While he was associated with the General Electric Company, Schenectady, N. Y., from 1897 to 1904, he spent five years as assistant to C. P. Steinmetz on a-c machinery design. In 1910 he was appointed professor and head of the department of electrical engineering at Columbia University and has been professor emeritus since 1941. At present he represents AIEE on the board of the Engineering Library and on the Engineering Foundation board. Recently he served on the AIEE committee on Inter-American Engineering Co-operation and as AIEE representative on the joint committee on Inter-American Engineering Co-operation. He was chairman of the special committee on pension plans from 1937 to 1943.

E. H. Bailey (A '18, M '40) district transformer specialist, General Electric Company, Atlanta, Ga., recently was elected president of the Georgia Engineering Society. Mr. Bailey was chairman of the Georgia Section of AIEE for 1940–41.

OBITUARY • • • •

Richard C. Engelken (M '33) partner, Hamel and Engelken, New York, N. Y., died January 19, 1944. Mr. Engelken was born in New York, December 9, 1903, and was graduated from Cooper Union with the degree of bachelor of science in electrical engineering in 1926. He was first employed as an electrician's apprentice by Oberg, Blumberg and Bleyer, contracting engineers, New York, N. Y., in 1918 and 1919 and by the Universal Electric Stage Lighting Company, New York, from 1919 to 1922. In 1922 he entered the employ of the Electrical and Mechanical Service Company, New York, as electrical machinist and in 1924 he became engineering assistant in the distribution system of the Brooklyn (N. Y.) Edison Company with which he remained until 1928. He returned to the Universal Electric Stage Lighting Company, Inc., from 1928 to 1936 and during this time had charge of the engineering connected with the manufacture of arc and incandescent lighting equipment. In 1936 he joined the firm of Morgan, Hamel, and Engelken, New York, which became Hamel and Engelken in 1941. Recently as a representative of the Vitarama Corporation, Long Island City, N. Y., he had traveled widely for the War Department supervising the installation of antiaircraft gunnery equipment. In this connection he had toured the Pacific war area. Mr. Engelken designed many of the lighting effects at the New York World's Fair, the Hayden Planetarium, the Museum of Natural History and many New York night clubs and restaurants and installed the lighting systems at the Radio City Music Hall.

Edward Bedell Snyder (A '17, M '25) retired engineer, Charleston, W. Va., died December 17, 1943. Born in Charleston, December 5, 1881, Mr. Snyder received from Center College the degrees of bachelor of science in 1903 and master of arts in 1904. In 1903 and 1904 he was a member of the physics department faculty and in 1904 joined the Charleston Electric Supply Company where he worked on sales engineering matters connected with mining work. He commenced his 25-year association with the Ohio Brass Company in 1906 as head of the sales mining department, Mansfield, Ohio. In 1910 he was transferred to the high-tension insulator department and made manager of sales and commercial engineering. After a short period in 1920–21 as secretary and assistant manager of the Ohio Insulator Company, subsidiary of the Ohio Brass Company at Barberton, Ohio, he returned to his former position at Mansfield. In 1927 he was reappointed secretary of the Ohio Insulator Company, Barberton. Retiring in 1932 he practiced as a consultant until 1935 when he became assistant manager of the First Central Trust Company, Barberton. In 1939 he retired to Charleston. Mr. Snyder did much original research in connection with oils for insulators. He was instrumental in forming the West Virginia Section of the AIEE and served as its first chairman, 1940–41.

Arnold James Magley (A '24) chief engineer, Moloney Electric Company of Canada,

Ltd., Toronto, died December 22, 1943. He was born in Columbia City, Ind., November 27, 1891, and was graduated from Purdue University with the degree of bachelor of science in 1914. Joining the General Electric Company, Fort Wayne, Ind., as student apprentice in 1914 he later worked on general transformer design and drafting. In 1916 he entered the employ of the Moloney Electric Company, St. Louis, Mo., as transformer designer and after 1917 when he was transferred to Windsor, Ont., he added factory management to his duties. The Moloney factory was moved to Toronto in 1922 and Mr. Magley was appointed chief engineer.

MEMBERSHIP

Recommended for Transfer

The Board of examiners at its meeting on February 17, 1944, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Dibblee, John, asst. chief engr., Hydroelectric Power Commission, Toronto, Ont., Canada.

Hapgood, K. E., chief power engr. & Design div., Tennessee Valley Authority, Chattanooga, Tenn.

Terwilliger, C. V. O., prof. and head of elec. engg. dept., U. S. Naval Academy, Annapolis, Md.

Turner, H. M., associate professor, Yale University, New Haven, Conn.

4 to grade of Fellow

To Grade of Member

Ballantyne, W. M. H., inspection engr., Pennsylvania Water & Power Co., Baltimore, Md.

Ballard, W. C., prof. of elec. engg., Cornell Univ., Ithaca, N. Y.

Bronwell, A. B., associate prof. of elec. engg., Northwestern University, Evanston, Ill.

Chambers, C. C., associate prof. of elec. engg., University of Pennsylvania, Philadelphia, Pa.

Cox, V. L., assistant engr., General Elec. Co., Philadelphia, Pa.

Davison, A. E., transmission engr., Hydroelectric Power Comm. of Ontario, Toronto, Ont., Canada.

Graham, C. H., principal electrical engr., Puerto Rico Water Resources Authority, Santurce, P. R.

Grotsinger, John, mgr., elec. engg. div., Goodyear Tire & Rubber Co., Akron, Ohio.

Haase, H. W., testing engr., Kyle Corp., So. Milwaukee, Wis.

Harvey, H. F., elec. engr., Newport News Shipbuilding & Dry Dock Co., Newport News, Va.

Koso, K. W., elec. maintenance foreman, Kansas City Pwr. & Lt. Co., Kansas City, Mo.

Kyle, W. J., president, Kyle Corp., So. Milwaukee, Wis.

LePage, W. R., asst. director, Johns Hopkins Univ., Baltimore, Md.

Lowe, R. E., central station dept., General Electric Co., Newark, N. J.

McCurley, J. B., Lt. Comdr., U. S. Navy Dept., Annapolis, Md.

McGill, C. W., division head, Boston Edison Co., Boston, Mass.

McMillan, W. R., system supt., Union Electric Co. of Missouri, St. Louis, Mo.

Milne, F. J., toll engr., Bell Telephone Co. of Canada, Toronto, Ont., Canada.

Ostenbaugh, C. L., elec. distribution engr., Memphis Light, Gas & Water Div., Memphis, Tenn.

Pettinger, A. J., design engr., Westinghouse Elec. & Mfg. Co., Newark, N. J.

Rhoden, A. L., elec. engr., Humble Pipe Line Co., Houston, Texas.

Royal, A. B., design engr., The Louis Allis Co., Milwaukee, Wis.

Ryan, R. C., chief inspector, The Ohio Brass Co., Mansfield, Ohio.

Savage, P. R., mgr., Woodbury Telephone Co., Woodbury, Conn.

Tebo, G. B., supervising engr., Hydroelectric Power Comm., Laboratories, Toronto, Ont., Canada.

Velander, Edy, Director, Royal Swedish Institute of Scientific Engg. Research; present address, Washington, D. C.

Wolfe, A. K., District Mgr., Allen Bradley Co., Milwaukee, Wis.

Woth, T. J., central station engr., Westinghouse Elec. & Mfg. Co., Atlanta, Ga.

Yost, N. S., chief engr., Howell Electric Motors Co., Howell, Mich.

29 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical District. Any member objecting to the election of any of these candidates should so inform the national secretary before March 31, 1944, or May 31, 1944, if the applicant resides outside of the United States or Canada.

To Grade of Member

Bredahl, A. C. (Re-election), Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.

Brewster, T. P., A. T. & S. F. Ry. Co., Chicago, Ill.

Butterworth, J. W., Federal Tel. & Radio Corp., Newark, N. J.

Cage, J. M., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Caller, J. M., Sperry Gyroscope Co., Brooklyn, N. Y.

Chandler, F. E., Wisconsin Tel. Co., Milwaukee, Wis.

Chen, L. F., National Resources, Commission of China, New York, N. Y.

Dallas, J. P., Hughes Aircraft Co., Culver City, Calif.

Freeman, R. C., General Elec. Co., West Lynn, Mass.

Gardner, R. H. (Re-election), Hoover Co., North Canton, Ohio.

Hagen, E. F., American Tel. & Tel. Co., Denver, Colo.

Hall, A. C., Mass. Inst. of Tech., Cambridge, Mass.

Higdon, J. J., Rural Electrification Adm., St. Louis, Mo.

Hufnagel, M. M., Rust Engg. Co., Pittsburgh, Pa.

Littler, R. G. (Re-election), Kaiser Co., Inc., Portland, Oreg.

Lohse, A., Permanente Metals Corp., Palo Alto, Calif.

Long, T., C. G. Conn, Ltd., Elkhart, Ind.

MacLaren, D. B., U. S. War Dept., Fort Mason, Calif.

McWilliams, J. L., Rural Electrification Adm., St. Louis, Mo.

Moffett, G. A., General Elec. Co., Schenectady, N. Y.

Morrison, C. F., Harvard Underwater Sound Lab., Cambridge, Mass.

Moyer, E. E., General Elec. Co., Schenectady, N. Y.

Phair, H. W., Fairchild Aviation Corp., New York, N. Y.

Ross, I. E., Jr., Natl. Elec. Mfgrs. Assn., New York, N. Y.

Slater, S. I. (Re-election), Slater Elec. & Mfg. Co., Brooklyn, N. Y.

Thompson, L. R. (Re-election), N. Y. C. System, New York, N. Y.

Tucker, A. N., Mallory Metallurgical Products, Ltd., London, England.

Waite, R. (Re-election), Otis Elev. Co., New York, N. Y.

Whittle, H. A., Rural Electrification Adm., St. Louis, Mo.

Wrigley, W. G., Elec. Construction Co., Ltd., Bushbury, England.

30 to grade of Member

To Grade of Associate

United States and Canada

1. North Eastern

Bonner, H. M., Eastman Kodak Co., Rochester, N. Y.

Burpee, W. E., E. B. Badger & Sons, Co., Boston, Mass.

Byers, W. F., General Radio Co., Cambridge, Mass.

Chamberlain, J. E., General Elec. Co., Schenectady, N. Y.

Chun, C. J., General Elec. Co., Pittsfield, Mass.

Clark, D. L., Stromberg-Carlson Co., Rochester, N. Y.

Crowe, T. W. A., Jr., General Elec. Co., Schenectady, N. Y.

Crumb, S. F., General Elec. Co., Schenectady, N. Y.

Day, C. M., New England Tel. & Tel. Co., Boston, Mass.

Delaney, B. W., Public Serv. Co. of N. H., Manchester, N. H.

Donahue, B. L., Cutler-Hammer, Inc., Buffalo, N. Y.

Euler, G. M., General Elec. Co., Schenectady, N. Y.

Ewaskio, C. A., Harvard Underwater Sound Lab., Cambridge, Mass.

Fano, R., Mass. Inst. of Tech., Cambridge, Mass.

Griggs, R. E., General Elec. Co., Schenectady, N. Y.

Grosse, P. C., Mass. Inst. Tech., Cambridge, Mass.

Hadley, N. L., General Elec. Co., Schenectady, N. Y.

Hamm, W. G., Mass. Inst. of Tech., Cambridge, Mass.

Hartman, R. L., General Elec. Co., Schenectady, N. Y.

Henkel, R. L., Harvard Univ., Cambridge, Mass.

Ifland, J. J., Harvard Univ., Cambridge, Mass.

Johnson, J. O., Jr., Westinghouse Elec. & Mfg. Co., Boston, Mass.

Jones, D. W., Jr., General Elec. Co., Schenectady, N. Y.

Judd, H. R., Lieut. U.S.N.R., New London, Conn.

Kaibel, S. F., Harvard Univ., Cambridge, Mass.

Kearney, J. W., Harvard University, Cambridge, Mass.

Keller, E. W., Mass. Inst. Tech., Cambridge, Mass.

Ketcham, A. W., Ensign, U.S.N.V., Salisbury, Vt.

Lane, J. D., Harvard Univ., Cambridge, Mass.

Langewalter, F., Cornell Univ., Ithaca, N. Y.

Larew, J. J., General Elec. Co., Schenectady, N. Y.

MacKay, R. F., Worcester Poly. Inst., Worcester, Mass.

Maguire, L. N., 101 Hope St., Stamford, Conn.

Matson, H. E., General Elec. Co., Schenectady, N. Y.

Morrison, W. C., General Electric Co., Schenectady, N. Y.

Reeves, J. F., Mass. Inst. of Tech., Cambridge, Mass.

Rhoades, C. M., Jr. (Re-election), General Elec. Co., Schenectady, N. Y.

Riley, J. C., Harvard Univ., Cambridge, Mass.

Rivest, E. L., General Electric Co., Syracuse, N. Y.

Sargent, D. M., Mass. Inst. of Tech., Cambridge, Mass.

Talifarro, W. C., Mass. Inst. Tech., Cambridge, Mass.

Tucker, A. S., General Elec. Co., Lynn, Mass.

Wanc, H. T., Westinghouse Elec. & Mfg. Co., Springfield, Mass.

Wedel, J. J., Jr., Harvard Univ., Cambridge, Mass.

White, E. C., General Elec. Co., Schenectady, N. Y.

Wright, H. E. A., Westinghouse Elec. & Mfg. Co., Boston, Mass.

Wulfestange, J. F., Jr., Schiefer Electric Co., Syracuse, N. Y.

Wulfken, H. J., General Elec. Co., Schenectady, N. Y

Zeller, H. R., Mass. Inst. Tech., Cambridge, Mass.

2. Middle Eastern

Ashton, W. J., Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.

Begis, M. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Bissett, E. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Bonham, L. L., Naval Research Lab., Washington, D. C.

Booth, W. S., Ensign, U.S.N.R., Washington, D. C.

Bradley, J. M., Cincinnati Gas & Elec. Co., Cincinnati, Ohio.

Busse, C. C., Pvt., U. S. Army, Pittsburgh, Pa.

Colberg, J. C., Naval Research Lab., Washington, D. C.

Conway, J. G., 6930 Greenwood St., Pittsburgh, Pa.

Cook, M. E., Naval Research Lab., Washington, D. C.

Crane, A. H., Jr., Naval Research Lab., Washington, D. C.

Cuttino, W. H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Davidson, F. A., U. S. Engineers, Cincinnati, Ohio.

Davis, J. D. L., Westinghouse Elec. & Mfg. Co., Lima, Ohio.

Davis, R. T., U. S. Navy, Washington, D. C.

DeByle, W. C., Naval Research Lab., Washington, D. C.

Descalzi, R., General Elec. Co., Philadelphia, Pa.

Dykstra, G. G., General Elec. Co., Erie, Pa.

Emory, J. C., G. Martin Co., Middle River, Md.

Estrin, M. N.A.C.A., Cleveland Airport, Cleveland, Ohio

Field, E. J., Roller-Smith Co., Bethlehem, Pa.

Fishman, M., Carnegie Inst. of Tech., Pittsburgh, Pa.

Galbreath, D. H., General Elec. Co., Erie, Pa.

Gelinas, R. W., Westinghouse Elec. & Mfg. Co., Baltimore, Md.

Giusti, V. F., Lieut. U.S.N.R., Piqua, Ohio.

Goldston, A. C., I.T.E. Circuit Breaker Co., Philadelphia, Pa.

Goodell, C. E., Jr., Naval Ordnance Lab., Washington, D. C.

Gould, I. J. (Re-election), Bureau of Ships, Washington, D. C.

Graham, R. E., Sylvania Elec. Prods., Inc., Emporium, Pa.

Griffith, C. (Re-election), E. G. Budd Mfg. Co., Philadelphia, Pa.

Guyton, W. J., Allis-Chalmers Mfg. Co., Washington, D. C.

Hartmann, W. A., Jr., Naval Research Lab., Washington, D. C.

Heisler, D. E., Naval Research Lab., Washington, D. C.

Herbert, L. G., Johns Hopkins Univ., Silver Spring, Md.

Hermach, F. L., National Bur. of Standards, Washington, D. C.

Humphrey, J. T., Westinghouse Elec. Co., East Pittsburgh, Pa.

Hutchinson, C. E., Heinemann Circuit Breaker Co., Trenton, N. J.

Kletzel, G. W., Philco Corp., Philadelphia, Pa.

Knox, G. W., Westinghouse Elec. & Mfg. Co., Baltimore, Md.

Levin, M. J., Cincinnati Gas & Elec. Co., Cincinnati, Ohio.

Lynch, D. R., Westinghouse Elec. & Mfg. Co., Fairmont, W. Va.

Mason, M. F., Ohio Public Serv. Co., Elyria, Ohio.

McDonald, F. E., U. S. Engineers, Cincinnati, Ohio.

McHarg, C. A., Bureau of Ships, Washington, D. C.

McPherson, G., Jr., Naval Research Lab., Washington, D. C.

Merriam, F. R., N.A.C.A., Cleveland Airport, Cleveland, Ohio.

Midyett, W. M., Lieut., U. S. Army, Fort Dix, N. J.

Miley, A. M., Elec. Storage Battery Co., Philadelphia, Pa.

Mohan, J. T., Jr., American Tel. & Tel. Co., Cincinnati, Ohio.

Naidamast, D., Philco Radio & Tel. Corp., Philadelphia, Pa.

Payson, E. C., Lieut., U. S. Army, Aberdeen Proving Ground, Md.

Renoff, G. F., Johns Hopkins Univ., Baltimore, Md.

Rexford, D. L., I.B.M. Corp., Toledo, Ohio.

Rice, C. T., Princeton University, Princeton, N. J.

Saltzman, C. F., State College, Pa.

Sanborn, C. B., Jr., Naval Research Lab., Washington, D. C.

Schey, S. L., Pittsburgh Lectromelt Furnace Corp., Pittsburgh, Pa.

Schneider, C. A., Univ. of Cincinnati, Cincinnati, Ohio.

Schulz, R. B., Univ. of Penna., Philadelphia, Pa.

Sharples, T. K., University of Penna., Philadelphia, Pa.

Sherertz, P. C., Ensign, U.S.N.R., Washington, D. C.

Stoner, R. H., Goodyear Aircraft Corp., Akron, Ohio.

Taylor, A. D., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Tolbert, J. W., Allis-Chalmers Mfg. Co., Washington, D. C.

Trasatti, R. J., I-T-E Circuit Breaker Co., Philadelphia, Pa.

Unger, J. W., Princeton Univ., Princeton, N. J.

Watson, H. M., Westinghouse Elec. & Mfg., East Pittsburgh, Pa.

Weller, E. F., Jr., 2nd Lieut., U. S. Army, Charleston, W. Va.

Woods, T. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Woomer, K. E., Phila. Navy Yard, Philadelphia, Pa.

Worman, T. H., Island Creek Coal Co., Holden, W. Va.

3. New York City

Allen, H. B. (Re-election), New Jersey Pwr. & Lt. Co., Dover, N. J.

Allerton, G. L., Western Elec. Co., New York, N. Y.

Anselmi, R. F., Todd Shipyard Corp., Hoboken, N. J.

Atkins, J. W., Sperry Gyroscope Co., Garden City, N. Y.

Banks, J. H., Syncro Mach. Co., Rahway, N. J.

Barnett, G. F., Johns-Manville Research Lab., Manville, N. J.

Berkovitz, H., Westinghouse Elec. Elevator Co., Jersey City, N. J.
Brechman, G. E., New York Univ., New York, N. Y.
Bloser, E. C., Sperry Gyroscope Co., Garden City, N. Y.
Bleckman, J. N., Western Electric Co., Kearny, N. J.
Bridge, J. A., Federal Tel. & Radio Corp., East Newark, N. J.
Bright, H. S., Western Elect. Co., New York, N. Y.
Carter, J. C., Signal Corps, Camp Evans, N. J.
Colehower, G. H., Jr., Norden Labs. Corp., New York, N. Y.
Contrast, G. A., Sperry Gyroscope Co., Garden City, N. Y.
Covello, F. S., Ward Leonard Elec. Co., Mount Vernon, N. Y.
DelValle, P. B., Ford Instrument Co., Long Island City, N. Y.
DePass, E. T., Ensign, U.S.N.R., New York, N. Y.
Dewey, W. S., New York Tel. Co., New York, N. Y.
DiSarro, B., U. S. Navy Yard, Brooklyn, N. Y.
Drvostep, J. J., Sperry Gyroscope Co., Brooklyn, N. Y.
Dunn, H. F., R. C. A. Victor Div. of R. C. A., Harrison, N. J.
Echtman, L., School of Technology, C. C. N. Y., New York, N. Y.
Gault, W. E., R. C. A. Mfg. Co., Harrison, N. J.
Gentile, S. F., Western Elec. Co., Inc., Jersey City, N. J.
Getchell, W. A., Jr., Bell Tel. Lab., Inc., New York, N. Y.
Goodstein, L. D., Sperry Gyroscope Co., Garden City, N. Y.
Grove, A. W. (Re-election), H. Behlen & Bros., Inc., New York, N. Y.
Gulack, J. G., Federal Tel. & Radio Labs., New York, N. Y.
Guyonnet, M., Jr., Western Elec. Co., Kearny, N. J.
Hewson, K. D., R. C. A. Mfg. Co., Harrison, N. J.
James, W. S., Ward Leonard Elec. Co., Mount Vernon, N. Y.
Kahal, R., Sperry Gyroscope Co., Garden City, N. Y.
Lane, R. N., Gibbs & Hill, Inc., New York, N. Y.
Lang, P., Norden Labs. Corp., New York, N. Y.
Lauter, J. I., Ensign, U.S.N.V., New York, N. Y.
Ledwith, C. F. R. Harris, Inc., New York, N. Y.
Leef, G. R., Federal Tel. & Radio Corp., Newark, N. J.
Martin, S. J., Radio Televisions Inst., New York, N. Y.
McKay, J. R., Sperry Gyroscope Co., Garden City, N. Y.
Oster, H. A., New Jersey Bell Tel. Co., Newark, N. J.
Peterson, D. H., U. S. Navy Yard, Brooklyn, N. Y.
Powell, A. E., Federal Tel. & Radio Corp., Newark, N. J.
Rahnon, R. J., Schweitzer, Inc., Spotswood, N. J.
Reeder, W. F., New Jersey Bell Tel. Co., Newark, N. J.
Schreiber, C. R., Curtiss-Wright Corp., Caldwell, N. J.
Schwartz, R. J., Columbia Univ., New York, N. Y.
Seppanen, M. T., Sperry Gyroscope Co., Brooklyn, N. Y.
Smith, D. H., Bendix Aviation Corp., New York, N. Y.
Steiny, J., Federal Tel. & Radio Corp., Newark, N. J.
Stiner, M., Otis Elevator Co., Yonkers, N. Y.
Taylor, G., General Elec. Co., New York, N. Y.
Weiss, G., Liquidometer Corp., New York, N. Y.
Wiese, D. B., Westinghouse Elec. & Mfg. Co., Newark, N. J.
Wildken, H. J., Electrical Testing Labs., Inc., New York, N. Y.
Williamson, T. L. R., Pratt Institute, Brooklyn, N. Y.
Wolff, J. E., Emerson Radio Corp., New York, N. Y.
Ziegler, J. R., Norden Labs. Corp., New York, N. Y.

4. Southern

Alexander, F. C., General Elec. Co., Columbia, S. C.
Atkinson, C. A., Memphis Light, Gas & Water Div., Memphis, Tenn.
Brittain, J. B., Charleston Navy Yard, Charleston, S. C.
Brown, L., Tenn. Eastman Corp., Oak Ridge, Tenn.
Cheatham, R. E., Jr., Miss. Pwr. & Lt. Co., Jackson, Miss.
Farmer, A. L., Higgins Aircraft, New Orleans, La.
Googe, H. L., Southwestern Gas & Elec. Co., Shreveport, La.
Hayley, A. L., Jr., Louisville Gas & Elec. Co., Louisville, Ky.
Horning, R. B., General Elec. Co., Charlotte, N. C.
Kitchens, A. N., Jr., Tenn. Eastman Corp., Oak Ridge, Tenn.
Koutnik, E. A. (Re-election), Tenn. Eastman Corp., Oak Ridge, Tenn.
Lough, Holophane Co., Inc., Atlanta, Ga.
Means, C. P., Jr., U. S. Navy Yard, S. C.
Parker, J. E., Carbide & Carb. Chem. Corp., Louisville, Ky.
Pendray, T., Tenn. Valley Auth., Chattanooga, Tenn.
Roberts, C. A., Tenn. Valley Auth., Chattanooga, Tenn.
Senn, T. A., Jr., Norfolk Navy Yard, Portsmouth, Va.
Smith, T., Girdler Corp., Louisville, Ky.
Treis, J. P., Knoxville Elec. Pwr. & Water Bd., Knoxville, Tenn.
Votava, V., Tenn. Valley Auth., Wilson Dam, Ala.

5. Great Lakes

Adler, G. H., Public Serv. Co. of N. Ill., Maywood, Ill.
Bankson, H. D., Line Material Co., South Milwaukee, Wis.
Bellinger, T. F., Allis-Chalmers Co., Milwaukee, Wis.
Chadkewicz, A., Chrysler Corp., Detroit, Mich.
Clark, F. J., U. S. Army, Muncie, Ind.
Frontier, M., A.-C. Spark Plug Div., Flint, Mich.
Gill, R. L. (Re-election), Public Serv. Co. of N. Ill., Joliet, Ill.
Gilmer, J. A., American Tel. & Tel. Co., Chicago, Ill.
Hagren, G. L., Duplex Truck Co., Lansing, Mich.
Hart, J. A., General Motors Corp., Indianapolis, Ind.
Hollingsworth, C. A., Bendix Home Appl., Inc., South Bend, Ind.
Holm, J. P., Commonwealth & Southern Corp., Jackson, Mich.
Marshall, S. C., General Elec. Co., Fort Wayne, Ind.
McCollister, F. W., Dow Chemical Co., Midland, Mich.
McCurley, J. C., James Stewart & Co., Chicago, Ill.
Makinia, K., Allis-Chalmers Mfg. Co., West Allis, Wis.
Moehl, E. R., Univ. of Mich., Ann Arbor, Mich.
Nolan, F. M., Allis-Chalmers Mfg. Co., West Allis, Wis.
Osburn, C. U., General Elec. Co., Fort Wayne, Ind.
Paula, A., A. O. Smith Corp., Milwaukee, Wis.
Paulsen, W. E., Public Serv. Co. of Northern Ill., Maywood, Ill.
Potter, J. D., Northwestern Univ., Evanston, Ill.
Prandoni, E. L., Caterpillar Tractor Co., East Peoria, Ill.
Proudfoot, O. P., Cutler-Hammer, Inc., Milwaukee, Wis.
Regensteiner, C., Sargent & Lundy, Chicago, Ill.
Ritter, T. J., Line Material Co., South Milwaukee, Wis.
Schubert, W. C. (Re-election), Hercules Powder Co., Baraboo, Wis.
Sherwin, H. W., Michigan Bell Tel. Co., Detroit, Mich.
Straub, G. L., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Sundstrom, O., Illinois Light Co., East Peoria, Ill.
Takle, K. J., Illinois Inst. of Tech., Chicago, Ill.
Trefry, D. E., Detroit Edison Co., Detroit, Mich.
Walker, D. C., James Stewart Co., Inc., Chicago, Ill.
Willoughby, M. B., Republic Steel Corp., Chicago, Ill.
Wilson, C. H. (Re-election), Gen. Motors Corp., Grand Blanc, Mich.

6. North Central

Eklund, R. A., U. S. Bur. of Reclamation, Cheyenne, Wyo.
Potter, K. W., Public Serv. Co. of Colo., Denver, Colo.
Schacht, R. L., Consumers Pub. Power Dist., Lincoln, Nebr.

7. South West

Coffman, J. F., Kansas Gas & Elec. Co., Parsons, Kans.
Farley, J. C., Jr., Southwestern Power Adm., Denison, Texas.
Fullerton, F. W., Southwestern Bell Tel. Co., Oklahoma City, Okla.
Hankison, W. C., A. T. & S. F. Ry. Western Lines, Amarillo, Texas
Harrison, J. S., Cessna Aircraft Co., Wichita, Kans.
Keller, H., Aluminum Co. of America, Malvern, Ark.
Ketteringham, G. R., North American Aviation, Dallas, Texas.
Klumb, R. E., General Electric Co., St. Louis, Mo.
Laird, J. A., III, Kelly Field, Texas.
Lee, J. L., Gulf, Colorado & Santa Fe Ry. Co., Galveston, Texas.
Moore, R. I., Allis-Chalmers Mfg. Co., Tulsa, Okla.
Moorhouse, E. C., Cessna Aircraft Co., Wichita, Kans.
Nienhaus, E. J., Southwestern Bell Tel. Co., Oklahoma City, Okla.
Spencer, N. C., Gulf States Util. Co., Beaumont, Texas.
Stein, W. A., Washington Univ., St. Louis, Mo.
Whitaker, G. R., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Williams, W. F., Jr., Brown Shipbuilding Co., Houston, Texas.
Yoder, H. F., Beech Aircraft Corp., Wichita, Kans.

8. Pacific

Ackerman, J. M., Standard Oil Co. of Calif., San Francisco, Calif.
Adelfson, N. G., U.S.N.R., Winslow, Ariz.
Bennett, C. B., U. S. Naval Repair Base, San Diego, Calif.
Delaney, J. P. (Re-election), Bureau of Pwr. & Lt., Los Angeles, Calif.
Dimitroff, A. Z., Phelps-Dodge Corp., Jerome, Ariz.
Egerton, A. P., U. S. Naval Drydocks, Hunters Point, San Francisco, Calif.
Fore, J. G., Joslyn & Ryan, San Francisco, Calif.
Gilman, H. E., Jr., Smith & Lindstrom, San Francisco, Calif.
Haggard, J. B., General Elec. Co., Los Angeles, Calif.
Harer, W. S., U. S. Navy Yard, Mare Island, Calif.
Hutchings, J. X., U. S. Maritime Comm., Oakland, Calif.
Kenney, R. R., Lockheed Aircraft Corp., Burbank, Calif.
Kirchner, H. J., Douglas Aircraft Co., Inc., Santa Monica, Calif.
Kraiio, P., Douglas Aircraft Co., Inc., El Segundo, Calif.
Leicester, J. F., III., Sperry Gyroscope Co., San Francisco, Calif.
Malnerich, J. J., Lockheed Aircraft Corp., Burbank, Calif.
McAdams, L. J., Permanente Metals Corp., Permanente, Calif.
Neikirt, W. T., Line Material Co., San Francisco, Calif.
Roder, P. M., Dept. of Bldg. & Safety, Los Angeles, Calif.
Ruffin, E. J., Moore Dry Dock Co., Oakland, Calif.
Settle, A. O., Douglas Aircraft Co., El Segundo, Calif.
Shapiro, J. J., U. S. Naval Drydocks, San Francisco, Calif.
Wiedman, E., Southern Calif. Tel. Co., Los Angeles, Calif.

9. North West

Cole, W. L., DuPont Co., Richland, Wash.
Harding, J. P., Westinghouse Elec. & Mfg. Co., Seattle, Wash.
Johnson, O. J., Boeing Aircraft Co., Seattle, Wash.
Mills, B. C., State College of Wash., Pullman, Wash.
Nelson, E. A., Puget Sound Navy Yard, Bremerton, Wash.
Pearson, H. F., Washington Water Pwr. Co., Spokane, Wash.
Peterson, R. A., Boeing Aircraft Co., Seattle, Wash.
Russell, W. H., U. S. Engineers, Portland, Oreg.

10. Canada

Crawford, H. J., Toronto Trans. Comm., Toronto, Ont., Can.
Eaton, M. (Re-election), Shawinigan Chemicals, Ltd., Shawinigan Falls, Que., Can.
Gardiner, A. H., Can. Gen. Elec. Co., Peterboro, Ont., Can.
Laurence, B. R., Canadian West. Co., Ltd., Hamilton, Ont., Can.
Mathers, F. F., Can. Gen. Elec. Co., Ltd., Peterboro, Ont., Can.
McHenry, G. M., Canadian Gen. Elec. Co., Toronto, Ont., Can.
Nylin, M. E., University of Toronto, Toronto, Ont., Can.
Oldfield, W., Loblaw Groceterias Co. Ltd., Toronto, Ont., Can.
Olsen, E. C., Can. Gen. Elec. Co., Ltd., Peterboro, Ont., Can.
Ratcliffe, L. C., Bell Tel. Co. of Can., Toronto, Ont., Can.
Smith, J. A., Shawinigan Water & Pwr. Co., Shawinigan Falls, Que., Can.
Smith, K. G., R. C. A. Victor Co. Ltd., Montreal, Que. Can.
Thorne, E. C. (Re-election), Dept. of National Defence, Ottawa, Ont., Can.
Wilkinson, H. M., Can. Gen. Elec. Co., Ltd., Peterboro, Ont., Can.

Elsewhere

Aguirre, H. R., General Electric, S. A. Mexico, D. F., Mex.
Ahuja, R. L., Refineria Pemex, Atzcapotzalco, D. F. Mex.
Alfaro, A. D. S., Mexican Lt. & Pwr. Co., Mexico, D. F., Mex.
Arriacorreta, G., Consulting & Sales Engineer, Mexico, D. F., Mex.
Bates, C. R., Ferranti, Ltd., Hollinwood, England.
Cabral, S. G., Mex. Lt. & Pwr. Co., Ltd., Licenciado Verdad, Mex.
Cantu, T. G., Comision Federal Electricidad, Mexico, D. F., Mex.
Cervantes, A. L., Com. Nac. de Irrig., Mexico, D. F., Mex.
Christlieb, A., Cia Mex. De Maquinaria, S. A. Mexico, D. F. Mex.
Christlieb, A. I., Sociedad Electro-Mecanica, Mexico, D. F., Mex.
Davalos, E. O., Mexican Lt. & Pwr. Co., Ltd., Mexico, D. F., Mex.
DeLaTorre, I. G., Petrolees Mexicanes, Poza Rica, Ver., Mex.
del Busto, A. F., Mex. Lt. & Pwr. Co., Ltd., Mexico, D. F., Mex.
Enzastiga, F. V., Mexican Lt. & Pwr., Co., Ltd., Mexico, D. F., Mex.
Fernandez, A. P., Mexican Lt. & Pwr. Co., Ltd., Mexico, D. F., Mex.
Galan, L. G., Pachuca Lt. & Pwr. Co., Mexico, D. F., Mex.
Gall, M. E., Tech. Office, British Admiralty, Cardiff, Wales.
Garcia, G. S., Mexican Lt. & Pwr. Co., Mexico, D. F., Mex.
Gordillo, E. A., Refineria Pemex, Atzcapotzalco, D. F., Mex.
Lagarde, J. V., Cia Dist. Westinghouse, S. A., Mexico, D. F., Mex.
Llanos Mandujey, R., Cuban Tel. Co., Havana, Cuba.
Lomas, L. E. M., Mexican Government Rwy. Const. Dept., Mexico, D. F., Mex.
Martinez, E. C., Air Conditioning Contractor, Mexico, D. F., Mex.
Martinez, H. D., Nac. Financiera, S. A., Mexico, D. F., Mex.
Meyer, C. A., Cia. Dist. Westinghouse, S. A., Mexico, D. F., Mex.
O'ccelli, A. S., Lerma Project, Mexico, D. F., Mex.
Ochoa, C. F. del C., Com. Nac. de Irrig., Mexico, D. F., Mex.
Piasencia, A. O., City's Council of Guadalajara, Jal., Mex.
Rexach, W. S., School of Tropical Medicine, San Juan, P. R.
Rodriguez, F. A., Mexican Lt. & Pwr. Co., Mexico, D. F., Mex.
Rojas, M. A., Refineria Pemex, Atocapotzalco, D. F., Mex.
Ruiz, A. de S., Impulsora de Empresas Electricas, Mexico, D. F., Mex.
Ruiz, A. R., Mexican Lt. & Pwr. Co., Mexico, D. F., Mex.
Schmill, J. V., Mexican Lt. & Pwr. Co., Ltd., Mexico, D. F., Mex.
Solis, J. S., Westinghouse Elect. Intl., Monterrey, N. L., Mex.
Soto, E. S., P. R. Water Resources Auth., Muyagues, P. R.
Tattersfield, J. P., Babcock & Wilson, Ltd., Mexico, D. F., Mex.
Tello, G. M., General Supply Co., Mexico, D. F., Mex.
Uruchurtu, J. A. Gil, Com. Nac. de Irrig., Mexico, D. F., Mex.
Valentin, J., Mexican Lt. & Pwr. Co., Mexico, D. F., Mex.
Vargas, L. Z., CIA Impulcora de Empr. El S. A., Mexico, D. F., Mex.
Vidal, F. H., Com. Nac. de Irrig., Mexico, D. F., Mex.
Viegas, F., Brush Elect. Engg. Co., Ltd., Loughborough-Lines, England.
Voss, J. F., Panama Canal, Balboa, C. Z.

Total to grade of Associate
United States and Canada 299
Elsewhere 44

OF CURRENT INTEREST

Professional Engineering Act Held Unconstitutional

The Illinois Professional Engineering Act passed by the state legislature in 1941 and containing many of the provisions of the "model law" developed by the American Society of Civil Engineers and other societies was declared unconstitutional by Judge Victor Hemphill in the Circuit Court of Sangamon County, Ill., on November 23, 1943. The case is under appeal to the Illinois Supreme Court and hearing has been set for the March 1944 term.

The major grounds of Judge Hemphill's ruling apply to the law's definition of professional engineering which corresponds to that proposed by the "model law" and those already incorporated into the laws of about 20 states. According to his opinion:

> If the act leaves to ministerial officers the definition of the thing to which the act is to be applied, such definition not being commonly known, it is invalid as an unwarranted delegation of power.

The opinion further states that such delegation of power is void and goes on to say that the legislature has not told the Department of Registration and Education, the administrative agent, what services require the application of engineering principles and data or what services involve public welfare, life, health, or property. The clause exempting "other recognized professions or trades" also was singled out as unconstitutional.

Although the action, if allowed to stand in Illinois, has no direct bearing on the laws in other states, it would serve as sufficient precedent for other suits in states having the same definition and similar constitutions.

The Illinois law was to become effective in August 1943, and suit was brought in July 1943 by a manufacturer of screens to restrain the director of the Department of Registration and Education from enforcing the act. It was defended by the Attorney General of the State, and the Illinois Engineering Council employed counsel who appeared as friend of the court. In the appeal to the Supreme Court, the Engineering Council has been granted leave to intervene as a defendant.

INDUSTRY . . . . .

Brazil Increases Motor Production

The electric motor industry in Brazil has increased production more than 100 per cent each year since 1940. This year Brazil expects to produce locally two thirds of the electric motors needed to meet domestic requirements and hopes to import the other one third from the United States. Prior to the war, Germany supplied 37 per cent of the Brazilian market, and the United States contributed 40 per cent.

At present there is great demand for motors to operate machine tools, pumps, compressors, and refrigerating equipment. Polyphase motors from $\frac{1}{2}$ to 50 horsepower are practically the only type of motor produced, however, and the cost ranges from 25 to 100 per cent higher than that of the United States product. Thus, it is expected that at the close of the war there will be a market in Brazil for fractional-horsepower single-phase motors for domestic and industrial appliances, and for large industrial polyphase types for operating machinery and supplying motive force to such industries as sugar mills, mines, canneries and vegetable-oil mills, paper mills, and metallurgical industries.

Changes Announced in Bureau of Standards Frequency Broadcast

Two changes are announced in the standard-frequency broadcast service of the National Bureau of Standards: the addition of a new radio frequency, 2,500 kilocycles per second, at night; and the omission of the pulse on the 59th second of every minute. The service comprises the broadcasting of standard frequencies and standard time intervals from the bureau's radio station WWV near Washington, D. C., continuously day and night (*EE, Sept '43, pp 424–5*).

There is on all carrier frequencies a pulse of 0.005-second duration which occurs periodically at intervals of precisely one second. The pulse consists of five cycles, each of 0.001-second duration and is heard as a faint tick when one is listening to the broadcast. It provides a useful standard of time interval for purposes of physical measurements and may be used as an accurate time signal. The pulse for the 59th second of every minute is now omitted.

North American Philips Company Opens Laboratory

Establishment of a new electronics laboratory at Irvington, N. Y., recently was announced by Pieter van den Berg, vice-president and general manager of North American Philips Company, New York, N. Y. The appointment of O. S. Duffendach, formerly professor of physics, University of Michigan, as research director of the laboratory was announced simultaneously.

The laboratory is part of the company's plans for extending its activities in the electronics field, and fundamental research in chemistry and physics is contemplated. At present the North American Philips Company is continuing, with reduced numbers of products, the manufacture of the specialties which built up the Philips Company in Eindhoven, Holland, before the war, when it manufactured lighting, radio, television, X-ray, and sound-film equipment, and metallurgical, glass, and plastics products. Production of quartz crystals, oscillator plates, cathode-ray tubes, X-ray equipment, tubes, fine wire, tungsten and molybdenum products, and other electronic devices have occupied the North American company, since it was incorporated in 1942 under the laws of Delaware, in an effort to make full use in the war program of all the resources, management, and engineering personnel; technical knowledge; and funds which it has accumulated since the Philips Company was founded in 1891 in Holland. Before the war 45,000 persons were employed by the company throughout the world, 20,000 of them in Holland.

Mr. van den Berg emphasized the fact that the North American company will endeavor "to earn a worthy place in the ranks of manufacturers of industrial electronics equipment in America. It will always be an American company and will not be dependent on help from outsiders in its development."

In addition he pointed out that after the war the North American company would have the asset of being able to draw upon all the technical resources of Philips companies in Holland and elsewhere and to call on associated plants in England, Australia, New Zealand, and South America for co-operation.

New D-C Resistance Welder Uses Storage Batteries

A d-c resistance welder using storage batteries as a source of welding current has been produced by Progressive Welder Company, Detroit, Mich., and is now in use welding aluminum for aircraft assemblies. The use of batteries as a source of stored energy makes possible the application of resistance welding in localities where power-supply limitations have prevented the use of other forms of stored-energy welders. The only requirement is sufficient power to operate a battery charger. Compared with other forms of stored-energy welders, the use of batteries for the power source means a material reduction not only in initial cost of the welding installation but also in operating costs, particularly in current consumption, maintenance costs, and supervisory requirements. The simplicity of the contactor-controller and the elimination of transformers, synchronous heat controls, and so forth, make it possible to maintain the equipment with only a normal amount of mechanical skill, it is claimed.

120,000-Rpm Motor Developed

An electric motor operating at the speed of 120,000 rpm has been developed by General Electric Company for application to internal grinding machines used in finish-grinding small holes, many less than one-quarter inch in diameter, in vital war parts. It may also be used to drive small drill chucks for drilling tiny holes in soft metals, using drills $\frac{1}{32}$ inch in diameter or less. The motor will not be available for general use until after the war.

With normal voltage applied at 2,000 cycles, the motor reaches full speed in less than a second. It is rated three horsepower and weighs but seven pounds as contrasted with the standard three-horsepower 1,800-rpm motor which weighs 105 pounds. The motor is so small that it fits into the palm of a person's hand, and its rotor is scarcely larger than a man's thumb. Tests the motor has passed successfully at 120,000 rpm include eight-hour continuous runs at rated horsepower as well as grinding tests with a tiny grinding wheel mounted directly on the motor shaft.

Problems entering into the design of the motor were chiefly of a mechanical nature. Since the utmost in smooth operation is an essential to precision grinding, ultraprecision bearings with practically perfect dynamic balance were required. A special oil-mist lubricated type of bearing is used. The amount of material used in the motor is so small, with a consequent reduction in radiating surface, that water cooling is utilized, one-half gallon a minute being used.

Brazil's New National Motor Factory Begins Production

Brazil's fastest-growing most modern factory, the National Motor Factory, which was scheduled to begin production early in January 1944, will be the first plant in Latin America to build airplane engines from start to finish. Located in the foothills of the Serro do Mar mountains about 22 miles from Rio de Janeiro and near the main line of the railroad running between Rio de Janeiro and Petropolis, the $9,000,000 plant will soon be producing enough engines and parts from Brazilian resources to help power United Nations' aircraft.

Largely responsible for the conception and development of the National Motor Factory is Air Brigadier Antonio Guedes Muniz of the Brazilian Air Force, who realized that, because of her vast area and varied terrain, Brazil's transportation future would entail increasing use of aviation services. When war came to the Americas the military importance of such a plant became evident, and immediate construction of the National Motor Factory became vital to the defense of the Western Hemisphere.

Although plans for the factory began taking shape in 1940 when General Muniz, then an Air Force colonel, was sent on a two-month government survey trip to select a suitable factory site, there had to be many conferences between Brazil and the United States as to authorization and financing of the project before approval was satisfactorily concluded, and actual construction did not get under way until July 1942. In the interim, progress was halted, because many priorities on machinery could not be honored in the face of a developing critical world situation, and then resumed when it was agreed that the factory would be included in the United States Lend-Lease assistance to Brazil. After American experts changed the plant design somewhat, a contract was signed with the Wright Aeronautical Corporation, authorizing the manufacture in Brazil of the Wright Whirlwind 450-horsepower airplane engine.

Since 1942, the project has been rushed to swift completion. The 700-foot-long windowless factory building has been fully equipped with air conditioning and fluorescent lighting. Like other Brazilian structures, it is made of reinforced concrete, and to maintain thermal control in the building the roof is lined with soft natural sand from northern Brazil. Its equipment is all-American of the very latest type, and the plant design and methods of production have been and will be patterned closely on the North American model.

Emphasis at the National Motor Factory is on an overhead power system, with the machinery not bolted to the floor, to facilitate future movement. An electrical control station with a view dominating the entire internal plant area will centralize factory control in one man. Crankcases and aluminum parts will be made on one side of the factory, while steel parts and crankshafts are being fabricated on the other side. Castings will be fed into the plant from the aluminum and brass foundry that is fast taking shape.

Brazilian engineers are now studying at the Wright plant in Paterson, N. J. Upon returning to Brazil, aided by North American experts they will teach 1,000 specially selected workmen in the craft of engine building. Top production for the plant has been estimated at more than 500 Wright Whirlwinds a year on one eight-hour shift and twice that for two shifts. Later it is expected that the plant will build plane engines up to 1,200 horsepower.

General Muniz foresees vast technological changes for Brazil arising from the operation of the National Motor Factory. He said: "This factory will show Brazilians new techniques in making mechanical parts and in erecting factories on the American, not the European, design. . . . For the first time we will be using the finest American precision tools on a large scale. Heretofore, Brazilian manufacturers have been inclined to buy British and German machine tools, since they were slightly cheaper than the American ones. This war, however, is showing each day that American tools have not only unsurpassed quantity output but also unmatchable quality. Once Brazilians see for themselves how these instruments work, they will be content with no other."

Postwar Foreign Markets for U. S. Electrical Goods Estimated

In a statistical study and project recently made by the Bureau of Foreign and Domestic Commerce, "Foreign Trade After the War," attempt has been made to appraise the probable magnitude and distribution of foreign markets for postwar electrical goods.

The percentage of United States production reaching foreign markets is uncertain, since the amount of electrical devices incorporated in machines and equipment may add one third to one half to the total, but it varies usually from two to four per cent of production. In the past, American manufacturers have shared less in the foreign markets in proportion to their production than any other country, but this proportion is expected to increase.

In the present survey, the projects and plans for expansion in foreign countries were tabulated, and the percentage which may be filled from the United States was estimated. Since all calculations were based on probable rather than actual statistics, the results are largely hypothetical, but if the conditions assumed by the report are reached and the total exports of electrical goods in 1948 amount to $195,000,000 as was estimated, then the distribution indicated in the accompanying table will be a possibility.

Abstracted from "Brazil's New National Motor Factory," by the Office of the Coordinator of Inter-American Affairs, *Foreign Commerce Weekly*, December 25, 1943.

Table I. United States Export Percentage of Electrical Goods for 1948 Foreign Markets

Types of Equipment	Millions of Dollars
Generators, converters, arc-welding and generator parts and accessories	14.0
Primary batteries	5.3
Secondary batteries	5.0
Transformers	6.3
Power switches, lightning arresters, etc.	4.0
Power switchboards	2.0
Meters and testing equipment	6.5
Motors and parts	20.0
Motor controls	4.0
Electric locomotives	2.0
Station and warehouse trucks	.4
Portable electric tools	2.0
Electric lamps	2.0
Lighting fixtures	5.0
Electric refrigerators	24.0
Other motor-driven household appliances	7.5
Domestic heating appliances	2.0
Industrial electric furnaces	2.0
X-ray and therapeutic apparatus	3.5
Radio-transmitting and receiving apparatus	33.0
Wire-communication apparatus	6.0
Wiring devices	7.5
Other electrical appliances	31.0
Total	195.0

Slide Rule Checks Size of Circuit Breakers. A slide rule which offers a simplified means of determining the correct-size air circuit breakers for industrial substation applications has been made available by Allis-Chalmers Manufacturing Company. With this "unit-sub rule," one can calculate the interrupting capacity of the 600-volt class air circuit breakers needed for control of power in all industrial plants. The rule has been constructed from standard AIEE formulas for determining short-circuit currents and takes into consideration necessary factors, such as motor load and d-c component. The engineering information given in the rule is available also in nomogram form in the manufacturer's unit substation bulletin *B*6285. Write Allis-Chalmers Manufacturing Company, Milwaukee, Wis., for the slide rule or bulletin.

WAR PROGRAM . . .

X Ray Locates Foreign Bodies on Horizontal and Vertical Planes

The biplane marker and reorientation device, a field-hospital X ray, which localizes slugs and fragments in wounded men in two planes, vertical and horizontal, and makes it possible for surgery to be performed without moving the patient, has been designed by engineers of Westinghouse Electric and Manufacturing Company, according to announcement by Colonel Alfred A. de Lori-

mier, commandant of the Army's school of roentgenology. The device not only locates foreign bodies but marks the wounded man with iodine to guide the surgeon in making an accurate incision.

The X-ray division of the Westinghouse Electric and Manufacturing Company, Baltimore, Md., has been awarded an Army contract for almost 2,000 of these devices, which will be put into service on the fighting fronts.

WPB and Labor Department Plan Safety Campaign

An antiaccident agreement has been announced by the War Production Board and the Department of Labor through which the two agencies will pool their forces to reduce the toll of industrial accidents that result annually in a loss of life six times as great as the Nation sustained at Pearl Harbor.

In announcing the antiaccident agreement, WPB Chairman Donald M. Nelson said:

> In 1943, 56,800,000 man-days were lost from essential production, and 18,400 workers died because of industrial accidents. This vital blow at America's war production goes unrecognized by too many of us who were shocked into instant action by the loss of 3,303 lives among our Armed Forces at Pearl Harbor. Such a defeat on the production line cripples our war effort just as certainly as a major military defeat in the field.

The agreement between the WPB office of labor production and the Labor Department's division of labor standards is a step toward carrying out the comprehensive antiaccident campaign launched recently by WPB, in co-operation with various federal agencies, labor unions, industrial groups, and other private organizations. Among the groups participating in the campaign are American Federation of Labor, Congress of Industrial Organizations, United States Chamber of Commerce, National Association of Manufacturers, and National Safety Council.

The administration of the antiaccident campaign within WPB is being handled by the industrial health and safety section of the Office of Labor Production, headed by WPB Vice-Chairman Joseph D. Keenan. The agreement between WPB and the Labor Department will facilitate utilization by WPB of the nation-wide field staff and facilities of the division of labor standards. The staff of the division of labor standards consists of 22 full-time safety engineers and 600 volunteer special agents.

Under the terms of the agreement, the industrial health and safety section of the WPB labor production office will carry out such functions as follows:

1. Receive reports, suggestions, and complaints dealing with the industrial hygiene and the safety of war workers.

2. Act as a central clearing house in the War Production Board to check and refer these data for remedial action by the proper Federal agencies operating in the field of health and safety.

3. See that labor unions, management, and labor–management committees avail themselves of educational material on health and safety in general or in relation to particular industries.

4. Work with Government agencies and with labor and management to ensure that local labor and management representatives co-operate with Federal and State agencies in developing and executing remedial health and safety programs in designated critical war-industry areas.

The agreement provides that the safety and health branch of the Department of Labor's division of labor standards carry out the following activities:

1. Co-operate with management, labor, state labor departments, the American Standards Association, and other safety agencies in drafting safety codes and regulations.

2. Analyse and serve as a central clearing house for information on safety laws and regulations and their administration.

3. Prepare and publish pamphlets, leaflets, and posters on industrial safety and health.

4. In co-operation with the United States Office of Education, conduct training courses for supervisory personnel and for safety representatives of unions.

Industry Urged to Renew Scrap Iron and Steel Contributions

An urgent appeal is being made to industry to step up its collection of industrial scrap. Although industry has responded magnificently to the national scrap drive in the past, a round-the-world war requires a constant, round-the-clock scrap support. Vast quantities of iron and steel scrap are still available, and in industry, especially, there exists the heavy scrap that is so much needed.

Industrial-salvage officials of the War Production Board have observed a steady dangerous downward trend in reports of dealers' scrap iron and steel inventories during the past year. According to a comparison breakdown by the United States Bureau of Mines covering a period from October 1942 through September 1943, shipments of heavy iron and steel scrap declined from 498,787 to 235,840 gross tons—a total of more than one half within eleven months.

Robert W. Wolcott, chairman of the American Industries Salvage Committee, declares that the normal spring increase in inventory cannot be expected, as the difficulty in the lack of man-power, transportation, and collection facilities now evident will only be accentuated. What remains is for industry to re-examine its assets of capital goods—to take another look, and to keep looking—for further opportunities of providing scrap iron and steel for imperative production demands.

"Salvage Manual for Industry," a 244-page volume recently published by the technical service section of the industrial-salvage branch of the WPB, is being distributed to executives interested in taking advantage of its suggestions for conducting a thorough-going scrap and salvage campaign. Copies of the manual can be purchased from the Superintendent of Documents, Washington, D. C., for 50 cents each.

In addition to the other considerations which may determine whether or not a piece of machinery or some of its parts should be scrapped, the Business Press Industrial Scrap Committee calls attention to the fact that industrial plants may claim a tax deduction on obsolete machinery, tools, and equipment consigned to the scrap pile. The Treasury Department, in general, has made allowance for losses sustained as a result of scrap and salvage operations. The theory of this application is that any taxpayer who scraps a capital asset is entitled to a deduction equal to the difference between the depreciated cost of the asset and its salvage value. Management has also been advised of the soundness of segregating its gross tonnage of scrap so as to realize full replacement value on the usable materials, and full cash and refund value on the segregated and prepared tons of scrap.

OTHER SOCIETIES •

Midwest Power Conference to Be Held April 13–14

War and postwar problems will keynote the seventh annual Midwest Power Conference, arranged by Illinois Institute of Technology, which will be held April 13 and 14 at the Palmer House, Chicago, Ill., according to announcement by Stanton E. Winston, acting head of the mechanical-engineering department at Illinois Institute and director of the conference.

The conference which will feature the theme, "Power Brings Victory," will include three electrical meetings and sessions on power-plant practice, industrial power plants, plant maintenance, fuels, and Diesel power. Among the speakers will be Alex D. Bailey, assistant to the vice-president of Commonwealth Edison Company, Chicago, who will speak on "Postwar Planning of the Nation's Power Supply," and J. A. Krug, director of the office of war utilities of the War Production Board, Washington, D. C.

AIEE and American Society of Mechanical Engineers will each sponsor a conference luncheon. Speakers at these sessions will be B. W. Clark, vice-president in charge of sales, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and C. O. Dohrenwend, chairman of engineering mechanics research at the Armour Research Foundation, Illinois Institute of Technology, Chicago.

The eight engineering societies included in the planning and sponsoring are: Chicago sections of American Institute of Chemical Engineers, AIEE, American Institute of Mechanical Engineers, ASME, Illinois sections of American Society of Civil Engineers and American Society of Heating and Ventilating Engineers, Western Society of Engineers, and Engineers' Society of Milwaukee. Schools working with Illinois Institute in sponsoring the conference include: Iowa and Michigan State Colleges, and Northwestern, Purdue, Iowa, Illinois, Michigan, and Minnesota universities.

List of Process Control Terms Issued by ASME

A revised list of process control terms and definitions has been prepared by the terminology committee of the industrial instruments and regulators division of American Society of Mechanical Engineers and will be presented for adoption by the division after all interested persons have had an opportunity to study the terms and offer comments. The list comprises a total of 45 definitions classified under five headings: general automatic control terms; types of automatic controller action; elements of automatic controllers; terms related to controller adjustment; and basic characteristics and elements.

All those interested, regardless of affilia-

tion, are urged to send suggestions and criticisms before June 15 to H. F. Moore, chairman, terminology committee; industrial instruments and regulators division, ASME; Post Office Box 37, Elizabeth, N. J. Criticisms of the list should be accompanied by specific suggested changes, insofar as possible. Reprints of the list, which is being published in the March issue of *Mechanical Engineering* may be obtained from ASME, 29 West 39th Street, New York 18, N. Y., upon request.

National Safety Council Offers Service for Small Organizations

The National Safety Council announces a new membership service designed exclusively to fit the needs of industrial organizations with 100 employees or less.

A recent survey of hundreds of industrial organizations in this size group, covering seven different industries, showed that the average accident frequency rate for these organizations was 47 per cent higher than the average for the largest organizations in the same industries, according to Ned H. Dearborn, executive vice-president of the council. In every industry studied the average frequency rate for small organizations, in every case, was higher than the average for the entire industry, he said.

The small-unit memberships will include the following services:

1. A safety manual on what management should know about organization and operation of an industrial safety program.

2. Supplies of accident prevention charts and safety inspection check lists.

3. Monthly poster service with selections made especially for small-unit operations.

4. Master copy of a "letter to employees" on a timely safety subject, the letter to be reproduced, signed, and distributed in the way the member feels is most effective.

5. Monthly issue of a safety instruction poster.

6. A year's subscription to *National Safety News*, official magazine for Council members which will contain a section devoted exclusively to the problems of this type of member.

In community council localities the member will, in effect, get two memberships in one—his community safety council, and a special membership in the national organization. In localities where community safety councils exist, the new memberships will be accepted exclusively through them. In areas not served by community councils, inquiries should be directed to the National Safety Council, 20 North Wacker Drive, Chicago, Ill.

Future Meetings of Other Societies

American Society for Testing Materials. Spring meeting, March 1–2, 1944, Cincinnati, Ohio; 47th annual meeting, June 26–30, 1944, New York, N. Y.

American Society of Mechanical Engineers. Spring meeting, April 3–5, 1944, Birmingham, Ala. Semi-annual meeting, June 19–20, 1944, Pittsburgh, Pa.

Electrochemical Society. Spring meeting, April 12–15, 1944, Milwaukee, Wis.

Midwest Power Conference. April 13–14, 1944, Chicago, Ill.

National Electrical Manufacturers' Association. April 23–7, 1944, Chicago, Ill.

National Fire Protection Association. May 8–11, 1944, Philadelphia, Pa.

EDUCATION • • •

Stevens Institute Organizes Foundation for Research Purposes

Organization of the Stevens Research Foundation, a nonprofit corporation to carry on scientific and industrial research in co-operation with Stevens Institute of Technology, was announced recently by Harvey N. Davis, president of the college. The stipulated purposes of the Foundation are to test and develop the public, scientific, and commercial value of inventions, discoveries, and processes and to aid in obtaining patents.

The foundation is an outgrowth of the program of research that Stevens Institute has carried on in recent years which has expanded greatly during the war. Several of its laboratories are now engaged in confidential research for Government departments to aid the war effort, and they have also helped industry to increase and improve production. The Foundation will aim to help meet the new demands of the reconstruction era, including new products, new uses for old products, and new and improved manufacturing processes, after the war.

It is expected that the Foundation will concentrate on fundamental problems which may take several years to solve and which are of general interest and value to the public, to industry, and to government. Publications on the results of studies and experiments are contemplated. Research will be carried out independently and in co-operation with Stevens Institute and with industries and other agencies, institutions, and organizations under definite contracts. The first concrete projects under the research foundation will be those already existing or planned—powder metallurgy, towing tank projects, sound research, and others.

James McKeen Cattell, psychologist, and scientific editor and author, died January 20, 1944. Dr. Cattell, who held the world's first professorship in psychology at the University of Pennsylvania from 1888 to 1891, was born in Easton, Pa., May 25, 1860. After graduating from Lafayette College in 1880, he studied at Gottingen, Leipzig, Paris, Geneva, and Johns Hopkins University. Subsequently he taught at Bryn Mawr College and Columbia University. In later years he edited the *Psychological Review*, the *Scientific Monthly*, *School and Society*, *the American Naturalist*, American Men of Science, and Leaders in Education and was president of the Science Service which supplies scientific articles to newspapers. He was a firm believer in the value to society of psychological aptitude tests and his strong convictions on academic freedom more than once engaged him in controversy. He believed that the scientist was destined to be in the forefront of international co-operation. He held numerous honorary degrees and memberships in scientific societies. In 1923 he was awarded the gold medal of the Society of Arts and Sciences.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Practical Education in Wartime

To the Editor:

Philip W. Swain's article, "Practical Education in Wartime" (*EE, Dec '43, pp 534–7*) struck a responsive chord, because I, too, have found that reviewing a subject by the "primer" method has advantages. I am in agreement with the author's contention that one can learn a great deal more, and faster, from a "primer" than from the usual text. Especially is this so if one must sandwich his study of such a book in among the many other demands of a busy day.

I am in the process of completing such a "beginner's" book, and it seems as though I have learned a great deal more about the subject than I can remember from my previous contact through a college text. As Mr. Swain points out, "such books often are written with more care and skill than those directed toward more advanced students." Also, I have found that some of the books have detailed problem solutions with answers accompanying all the practice problems. Why so many engineering textbooks are published without answers remains a mystery to me.

When a person is attempting to "brush up" on some past college course, or perhaps is endeavoring to work out a problem in a strange field, he is no longer interested in merely copying an answer but is seriously concerned with learning the mechanics of working out the solution to his problem. One of the best ways I have found, especially in involved electrical problems, is to follow through some problem worked out in a textbook. If one gets the same answer, he can feel fairly certain he has followed the right method. Without such a guide one cannot always be sure he is using the right approach.

From my experience in searching for "brush-up" books there appears to me to be a need for good "primers" in many lines, and I believe such books would be far more valuable for individual study if detailed problem solutions and practice-problem answers were included.

CARL R. ALBACH (A'43)
(Assistant engineer, design and estimating department, United States Engineers District Office, Kenmore, N. Y.)

NEW BOOKS • • •

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question.

Steel Man in India. By J. L. Keenan with the collaboration of L. Sorsby; introduction by L. Bromfield. Duell, Sloan and Pearce, Inc., New York, N. Y., 1943. 224 pages, 8½ by 5½ inches, cloth, $2.50. (ESL.)

This autobiographical narrative covers the experiences of an American steel man during 25 years with the largest steel-producing unit in India. Technical details, humorous reminiscence, and social and political discussion are intermixed throughout the book, giving an over-all picture of the development of the industrial age in India.

Plastics. By J. H. DuBois. American Technical Society, Chicago, Ill., 1943. 435 pages, illustrated, 8½ by 5½ inches, cloth, $3.75. (ESL.)

This is a simplified presentation of the manufacture and use of the important plastic materials and products, with tables of their properties and the basic information required by engineers and designers. The revised edition contains two new chapters on synthetic rubber and low-pressure laminates. The book is designed to be used both as a text and as a practical reference handbook.

Short Wave Wireless Communication. By A. W. Ladner and C. R. Stoner. Fourth Edition revised and enlarged, John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1943. 573 pages, illustrated, 8¾ by 5½ inches, cloth, $6. (ESL.)

Although this book deals especially with short-wave communication, the principles common to both long and short waves are introduced where necessary in order to achieve a self-contained treatise. The principles and equipment for short- and ultrashort-wave operation are discussed thoroughly in combination, instead of a separate chapter being devoted to ultrashort waves as in previous editions. A chapter on high-frequency therapeutic apparatus is included.

Industrial Safety. By T. O. Armstrong, R. P. Blake, J. J. Bloomfield, C. B. Boulet, M. A. Gimbel, S. W. Homan, W. D. Keefer, and R. T. Page, edited by R. P. Blake, foreword by H. T. Heald. Prentice Hall, Inc., New York, N. Y., 1943. 435 pages, illustrated 9½ by 6 inches, cloth, $5. (ESL.)

A series of chapters by authorities in the field provides a handbook useful to all industries. Subjects discussed include the history of industrial safety, causes of industrial accidents, accident prevention, inspection, safeguarding machinery, safety training and education, accident hazards, reports, and records. Fire prevention, first aid, and personal protective equipment are also covered in separate chapters. The book has been written from the viewpoint of the industrial worker on the job.

Luminescence of Liquids and Solids. By P. Pringsheim and M. Vogel. Interscience Publishers, New York, N. Y., 1943. 201 pages, illustrated, 9½ by 6 inches, cloth, $4. (ESL.)

Part I of this volume deals with the physics of luminescence, covering the theoretical background, experimental technique, and the properties of luminescent materials. Part II considers critically two main fields of application: fluorescence analysis for identification purposes, and luminescence of various types as light sources. A tabulated list of important fluorescent materials concludes the book.

Machinery's Handbook. By E. Oberg and F. D. Jones. 12th edition. Industrial Press, New York, N. Y.; sole distributors for the British Empire: Machinery Publishing Company, Ltd., 17 Marine Parade, Brighton, England, 1943. 1815 pages, illustrated, 7 by 5 inches, fabrikoid, $6. (ESL.)

In the 30 years since this work first appeared, it has become established as an almost indispensable work of reference in drafting rooms and machine shops. This new edition contains the same number of pages as the preceding one, but numerous changes have been made in charts and tables which bring them up to date.

Handbook of Tabular Presentation. By R. O. Hall. Ronald Press Company, New York, N. Y., 1943. 112 pages, illustrated, 11½ by 8½ inches, cloth, $3.50. (ESL.)

The designing and editing of statistical tables are discussed on the basis of broad practical experience in this book which will be useful to all who have to present data in tabular form. The principles presented are illustrated by a collection of tables which are discussed critically.

Fundamentals of Electrochemistry and Electrodeposition. By S. Glasstone. American Electroplaters' Society, New York, N. Y., 1943. 90 pages, tables, 8¼ by 5 inches, fabrikoid, $2. (ESL.)

The 20 chapters composing this small book are a reprinting of a series of articles which appeared in the *Monthly Review* of the American Electroplaters' Society. They describe in fairly simple language the fundamentals of electrochemistry as applicable to electroplating. The last chapter deals briefly with the causes and prevention of corrosion.

Double-Speed Synchronous Generator. (University of California Publications in Engineering, volume four, number three, pages 27–36.) By A. Tilles. University of California Press, Berkeley and Los Angeles, 1943. Illustrated, 11 by 8½ inches, paper, 25 cents. (ESL.)

A method is presented of operating a machine as a synchronous machine at twice its ordinary synchronous speed. The basic operating characteristics are given, and the behavior of the machine as a part of a system and in commercial application is indicated in a general way.

ASTM Standards on Paper and Paper Products. Prepared by ASTM committee *D*-6 on paper and paper products: Methods of Testing, Specifications. American Society for Testing Materials, Philadelphia 2, Pa., 1943. 138 pages, illustrated, 9 by 6 inches, paper, $1.35 ($1.00 to ASTM members).

ASTM Standards on Plastics. Sponsored by ASTM committee D-20 on plastics: specifications, methods of testing, nomenclature, definitions. 1943. 431 pages, illustrated, 9 by 6 inches, paper, $2 ($1.50 to ASTM members).

ASTM Standards on Textile Materials (with related information). Prepared by ASTM committee *D*-13 on textile materials: specifications, tolerances, methods of testing, definitions and terms. 1943. 457 pages, illustrated, 9 by 6 inches, paper, $2.25 ($1.50 to ASTM members). (ESL.)

These three publications are intended primarily to present in convenient form the ASTM standard and tentative standard methods of test and specifications pertaining to their respective subjects. Glossaries and descriptive nomenclature are included for the plastics and textile materials, and in the textile-materials volume abstracts are printed of three papers presented at a recent meeting

PAMPHLETS • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

November 1943 Supplement to the May 1943 List of Inspected Electrical Equipment. Underwriters' Laboratories, Inc., 207 East Ohio Street, Chicago 11, Ill., 55 pages.

Wage Incentives in Wartime. Consolidated Management Consultants, 521 Fifth Avenue, New York 17, N. Y., 47 pages.

The First Five Years Under the Natural Gas Act. Federal Power Commission, Washington, D. C., 24 pages, no charge.

Guide to Postwar Sales Planning. National Association of Manufacturers, 14 West 49th Street, New York 20, N. Y., 14 pages.

Guide to Internal Organization for Corporation Postwar Planning. National Association of Manufacturers, 14 West 49th Street, New York 20, N. Y., 14 pages.

United States Production, Consumption, and Stocks of Chemicals 1941–43. Chemicals Bureau, War Production Board, Bureau of the Census, Washington 25, D. C., 47 pages.

How Steel Castings are Serving America at War. Steel Founders' Society of America, 920 Midland Building, Cleveland, Ohio, 20 pages.

Mechanical Feed Water Regulation for Boilers. E. P. Culver, Northern Equipment Company, 1945 Grove Drive, Erie, Pa., no charge.

Jobs in Peacetime. National Association of Manufacturers, 14 West 49th Street, New York 20, N. Y., 18 pages.

TRANSACTIONS SECTION

Preprint of Corresponding Pages From the Current Annual AIEE Transactions Volume

Automatic Ticketing of Telephone Calls

O. A. FRIEND
MEMBER AIEE

THERE has recently been placed in commercial service in the Bell System a new arrangement of telephone switching equipment designed to enable telephone users in a metropolitan area to dial for themselves their calls to nearby points instead of placing them with an operator. This added central-office equipment has the distinctive feature that it automatically prepares an individual printed ticket showing the information needed for charging for the call. The initial installation serves some 8,000 subscribers at Culver City, adjoining Los Angeles. It enables them to dial directly, in the same way as local calls, their calls to various points within the Los Angeles metropolitan area and thereby enlarges the scope of their dial service, with its attendant advantages in speed and convenience.

This paper describes briefly the functions and design of this form of automatic ticketing, which is designed for use with central-office switching equipment of the step-by-step type. In addition to ascertaining and printing the information needed for billing, the equipment also incorporates features for routing calls economically through the trunking network. The plan in some respects resembles and in other respects differs from automatic ticketing arrangements developed abroad and used commercially in several networks in Belgium prior to the war.[1]

Present Methods of Handling Calls

Before describing the operation of the new system it may be well to review the present methods of handling telephone calls in metropolitan areas. The methods outlined below are, in essence, those used at Los Angeles, the largest city in the United States employing step-by-step equipment.

Figure 1 is an idealized map of a metropolitan area. The heavy circle represents the boundary of the city exchange; in general, it includes the closely built-up business, industrial, and residential regions, but is not identical with the municipal boundary. The city exchange may be divided into zones, shown dotted, used for determining toll rates for calls between various parts of the city and the several suburbs, and in some cases between the zones of the city itself. Surrounding the city are nearby suburban exchanges designated *A* to *H;* these may be well-separated communities, or may practically merge with each other or with the city. Farther out are other suburbs designated *M* to *T*. While such geographical regularity is not to be found in any actual city, this picture will serve to illustrate principles.

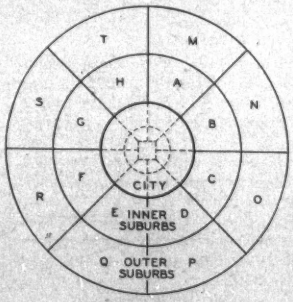


Figure 1. Idealized map of metropolitan area

The lines serving telephone subscribers terminate in central-office buildings located in the various exchanges. The city exchange has a number of buildings, some of which may house as many as five or six central-office switching units, the conventional central office having a capacity of 10,000 subscriber numbers. A suburban exchange may have one or several buildings each with one or a few central offices.

The switching plan for completing calls between subscribers in such a metropolitan area may be visualized by considering calls originating in a specific central office, for example, one in the suburban exchange designated *F*. Figure 2 shows in simplified form the switching plan of such an office. The subscriber lines are connected to dial switching equipment, which may be regarded as consisting of two parts designated "Originating" and "Terminating." The originating portion consists of the switching paths by which a call is routed to interoffice trunks. The terminating portion consists of the switching paths by which a call terminating in this office reaches the called subscriber.

Of the calls originated by a subscriber in this office the great majority will ordinarily be short-distance calls within what may be termed his local charge area, that is, the area within which his call is counted as one message unit if he subscribes to message-rate service, or is not counted if he pays for flat-rate service. This area may consist simply of his own exchange or may include certain nearby exchanges or zones. He dials these calls directly, if the area has been fully converted to dial operation. Such calls, in the typical case, go over direct trunks to the terminating office as illustrated at the lower left of Figure 2.

On calls to the more distant exchanges, for which there is a toll charge or a charge of more than one message unit, the subscriber dials "O" and passes his call to an operator. The switchboard provided for handling this and certain other types of traffic is included in Figure 2. The operator may complete the call by one of several methods, of which two are illustrated. If the called office is one for which there is enough traffic to warrant direct trunks, the operator extends the call over a direct trunk to that office and dials the last four digits of the called number. Many of the distant offices, however, receive too little traffic from this office to warrant an individual group of direct trunks and are reached through tandem switching equipment located at

Paper 44-49, recommended by the AIEE committee on communication for presentation at the AIEE winter technical meeting, January 24-28, 1944, New York, N. Y. Manuscript submitted November 15, 1943; made available for printing December 14, 1943.

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some central point in the area.[3] The operator extends such a call over a trunk to the tandem office and dials the complete number, thereby causing the tandem-office switches to select a tandem-completing trunk to the called office and the switches in that office to complete the connection. Whatever the method of completion, she writes a ticket showing the information needed for charging for the call.

Subscriber Dialing of Ticketed Calls

As previously stated, it is the purpose of the automatic ticketing equipment to make it unnecessary for the subscriber to place such calls with the operator but, instead, to permit him to dial them in the same way that he now dials local calls.

Figure 3 shows in block form the arrangement of switching equipment in the originating office when automatic ticketing of the type to be described has been added. In comparison with Figure 2, the amount of originating switching equipment is increased somewhat to provide paths for the added calls completed by dialing. The switchboard correspondingly is reduced. The direct and tandem trunks carrying ticketed calls, formerly appearing at the switchboard, are made accessible to the originating switches through added equipment which performs the two functions labeled "Routing" and "Recording."

The recording function presents the more novel features and will be considered first. The problems associated with it may be brought out by considering the form of record which the equipment is to produce.

Form of Ticket

Figure 4 shows a mechanically prepared ticket and a ticket of the type now written by the operator. On the operator's ticket the entry below the date is the calling party's number, ARdmore 8-2345, given by the subscriber at the time he places his call. Below are the called number and the times of end and start of the conversation period. The operator recognizes the answer of the called subscriber and the disconnect of both subscribers by observing the supervisory lamps of the cord circuit used for completing the connection and reads the corresponding times from a clock at her position whose dials show the hour, minute, and tenth of minute. The ticket provides space for entering later the conversation time, obtained by subtraction.

The automatically prepared ticket contains essentially the same information, shown, however, entirely as numerals in order to permit using a simple type of printing mechanism. The first entry is the calling number, the two letters of the office name being shown in terms of their numerical equivalents as they appear on the dial. The following group of seven digits shows to the tenth of an hour the time at which the call was made. Next is a group of three digits provided as an aid to maintenance; it shows which of certain units of common equipment were involved in the handling of the call. The called number is shown similarly to the calling number.

The following two digits, though printed together for space reasons, are independent. The first is the "class of service" of the calling subscriber. In some offices optional rates are offered to meet the needs of different types of subscribers, and the arbitrary digit showing this class is convenient for accounting purposes.

The following digit labeled "message units for initial interval" is the significant entry with regard to the charge for the call. The digit 3, for example, may represent a toll charge of 15 cents, or the addition of three message units to the subscriber's message usage. The equipment determines this figure from the destination of the call and the rate schedule of the calling subscriber. The figure applies to calls which do not extend beyond the initial five- or three-minute interval; on the relatively small percentage of overtime calls the overtime charge is subsequently added as an accounting procedure.

The information up to this point is printed on the ticket immediately after the subscriber dials his call. When the called subscriber answers, timing is started under control of a synchronous timer. When the subscribers hang up, the elapsed whole and fractional minutes are printed as minutes of conversation time. The time is normally shown as a two-digit number, but provision is made for printing additional digits for the rare calls that exceed 99 minutes.

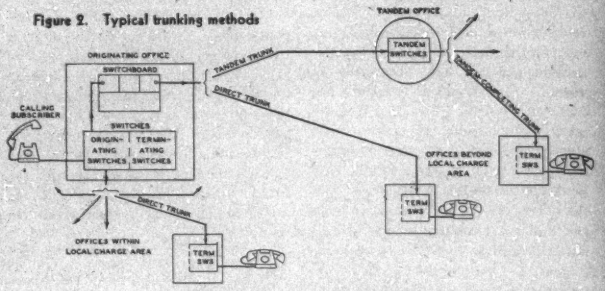
On a call which is not completed because of encountering a "busy" or "don't answer," or for any other reason, no conversation time is printed and the resultant short ticket is eliminated in the accounting process.

The arrangement of information on the ticket was chosen with regard to convenience of accounting procedures and minimizing of holding time of the various circuits involved in providing the information. Its size is that of the standard toll ticket written at long-distance switchboards and was chosen for convenience in handling and filing as well as to provide space for use with future mechanical accounting processes referred to later.

Message Ticketer

Figure 5 shows photographs of the machine, designated a "message ticketer," which prints and cuts the ticket. Power for rotating the type wheel is supplied by a small a-c motor through a friction clutch. An electromagnet controlled through a

Figure 2. Typical trunking methods



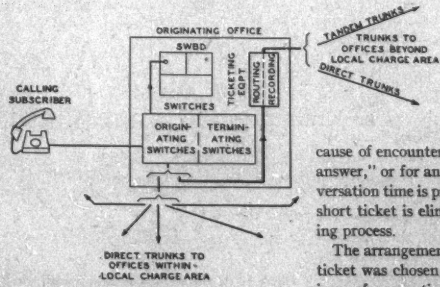


Figure 3. Trunking with automatic ticketing

commutator stops the type wheel, presses the paper against the character to be printed, and on its release steps the paper forward. A second magnet operates the knife. Mechanical simplicity is obtained by vesting control in external circuits connected to the ticketer when required through some 20 connecting leads. The printing speed averages about seven characters per second.

Functional Arrangement of Ticketing Equipment

The relationship of the major circuits of the ticketing system, one of which includes the message ticketer, is shown by the functional diagram, Figure 6. Each line of this diagram represents the total conductors comprising a connecting path; the path through the selectors normally consists of three conductors (the two wires of the talking circuit and a control wire), but other paths may consist of as many as 100 or more conductors. The symbols above the broken line represent, in very condensed form, the existing switching equipment of an office, while those below represent the major components of the equipment added for automatic ticketing.

The selectors shown above the broken line form part of the originating equipment of Figure 3. They consist of first, second, and third selectors which respond to the initial two or three digits of the called subscriber's number; these digits, which identify the office being called, are termed the office code. Each office corresponds to a level of these selectors. The levels corresponding to offices within the local charge area are shown connected to direct trunks leading to the respective offices. The levels corresponding to offices for which calls are to be ticketed are connected to ticketing trunk circuits and thence to the direct or tandem trunks over which the calls are to be completed.

Each trunk circuit consists of a group of relays and other telephone apparatus together with a message ticketer.

Associated with the trunk circuits there is provided a common group of senders whose functions will be described later. A sender is associated with a trunk circuit during the setting up of the call by way of an eight-wire step-by-step switch used as a trunk finder. Each sender consists of some 200 relays and other telephone apparatus used for controlling switching and recording operations.

The senders in turn have access to two or three "identifiers" which are the heart of the ticketing system. The identifier has the function of ascertaining the calling number and other equally important functions having to do with the routing of the call. It consists of 400 to 500 relays, a number of vacuum-tube circuits, and various other apparatus.

For ascertaining the calling number the identifier requires access to terminals corresponding to the numbers of all subscribers whose lines terminate in the building and who have access to the ticketing equipment. These terminals appear on the "thousand-number" circuits, of which there is one for each thousand consecutive numbers in the building.

Other paths for interconnecting various circuits for short periods during the establishment of a call are indicated on the diagram. They consist of multicontact relays which close through various numbers of wires as required for control and interchange of information between circuits.

"Day-and-hour" circuits connected to the senders control printing of the time of placing the call. Various minor circuits are omitted for simplicity.

The figures in circles show the quantities of the major circuits installed at Culver City for handling between 5,000 and 6,000 ticketed calls daily.

Method of Operation

The general operation of the system may now be traced. A subscriber making a call to a point for which a ticket is required dials the called number as listed in the directory. Dialing of the office code digits causes the call to advance through the selectors as on a local call, and to reach a level corresponding to the called office. This level, representing a destination for which calls are to be ticketed, is wired to a ticketing trunk circuit.

The trunk circuit causes a trunk finder to attach a sender, in which the further digits dialed by the subscriber are temporarily stored. The sender in turn calls in an identifier which performs two major functions. It provides the sender with information for routing the call, whereupon the sender sends out over the trunk the necessary pulses for setting up the call through distant switches. Concurrently, the identifier ascertains the calling number and furnishes the information to the sender. The sender, as an overlap with setting up the call, causes the message ticketer in the trunk circuit to print the initial information on the ticket. The identifier and sender are released when their respective functions have been performed.

When the called subscriber answers, apparatus in the trunk circuit starts timing. Finally, when the subscribers disconnect, the trunk circuit causes its ticketer to print the conversation time, after which it is freed for the next call.

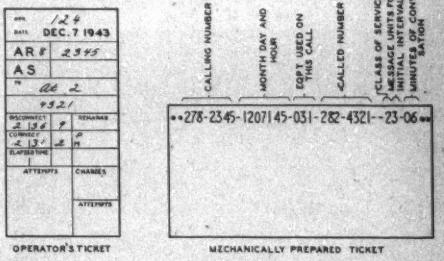


Figure 4. Tickets

OPERATOR'S TICKET

MECHANICALLY PREPARED TICKET

Calling-Number Identification

Identification of the calling number presents some features of interest. As shown in Figure 6, the identifier has access, through a multicontact relay connecting path, to the trunk circuit at which the call has arrived. It has access to all the thousand-number circuits through similar paths. The principle is simple. The identifier sends into the trunk circuit a signal which finds its way back through the selectors to the terminal associated with the calling subscriber's number in one of the thousand-number circuits. While sending the signal it rapidly scans these circuits, determining successively the thousand, hundred, ten, and unit digits of the terminal on which the signal appears. These digits are transferred to the sender, which controls their printing on the ticket.

Figure 7 shows the process in more detail. The signal used is an a-c potential of about five volts at 270 cycles, impressed by the identifier on the control wire of the path through the selectors; this signal does not interfere with the normal func-

tions of this wire, now affect the talking circuit. Connections of the control wires of the subscriber-line equipments to the thousand-number circuits are taken from terminals associated with the connector switches through which subscribers receive incoming calls and which therefore determine their respective numbers. These single-wire connections are cabled in numerical sequence to the thousand-number circuits, where each terminates in one contact of a multicontact relay and also in a capacitance-resistance network. One hundred consecutive networks may be connected in parallel to a "hundred" coil, and ten such coils are connected to a "thousand" coil. Therefore, when the a-c potential is applied to the control wire of the trunk, it follows the control wire back through the switches to the calling line and causes a signal to appear in the output winding of the appropriate "hundred" coil and "thousand" coil.

Each identifier has ten amplifier–detectors which it can connect through the thousand-number connectors to ten "thousand" coils. Finding a signal in one of them, it registers the digit designating that thousand on a group of register relays labeled *TH*. Through relay operations it then transfers its detectors to the ten "hundred" coils of that thousand. The hundred having been found and registered on the *H* register, the identifier operates the proper multicontact relays of the thousand-number circuit to connect those 100 terminals directly into the identifier. There it first groups them by tens and finally looks at the individual terminals of the ten, registering the ten and unit digits. The record of the number is transferred as received into the sender over a multilead connecting channel.

The foregoing describes identification within a central-office unit of 10,000 numbers. In buildings having more than one central office, the identifier first scans the central offices in succession, 10,000 or 20,000 numbers at a time, a second set of ten detectors being provided where the load warrants. The complete identification time averages less than two seconds.

The frequency of 270 cycles was chosen after a survey in working offices of extraneous potentials on control wires. The time and method of applying the detectors take account of the transients due to switching operations. Interlocks are provided to avoid conflicts when two or more identifiers are proceeding simultaneously. Check tests indicate irregularities due to wiring faults and provide second trials to overcome any contact irregularities.

Additional features are provided for differentiating between the two subscribers on two-party lines. These involve arrangements at the stations to produce different electrical conditions on the line, depending on which station is making the call, and a test of the line by the central-office apparatus. Facilities are not now being provided for differentiating between the stations on four-party or on rural lines, and calls from such stations will continue to go by way of the operator. Means are provided for preventing readily completion of calls through ticketing paths from these or other stations which for any reason are not to have direct dialing, without the necessity of segregating their lines in the switching equipment.

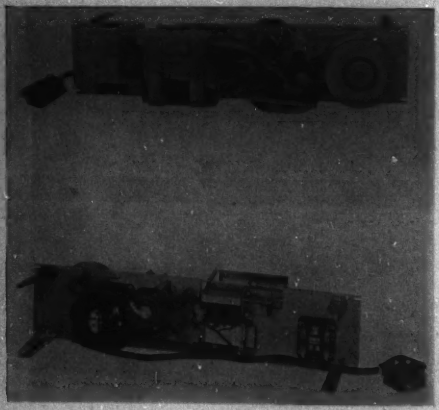


Figure 5. Message ticketer (front and rear views)

Class Identification

The a-c marking signal on the control wire of the switching path is used also for "class identification," which is not shown in Figure 7, in view of its similarity with the first stage of number identification. In a telephone exchange various classes of service may be offered, such as individual and party-line service with flat or message rates, or optional rate schedules differing in the extent of the local charge area. Some of these classes may require different types of equipment associated with the first selectors, or access to different paths reached by the selectors, and are accordingly segregated into appropriate line groups having access to corresponding groups of first selectors.

To enable the identifier to distinguish between classes, first selectors have networks of the type mentioned earlier associated with their control wires, and these are connected by selector groups to the proper ones of a few "class" coils. When a connection has been set up, this a-c path is therefore in parallel with that associated with the subscriber number. While the identifier is making number identification, other detectors are connected simultaneously to the class coils. The class indication thus ascertained is used for governing circuit functions and for printing the class on the ticket.

Routing Functions

As indicated in Figure 3, the second principal function of the ticketing equipment is to govern the routing of the call. This problem arises because of an inherent limitation of the simple step-by-step system with regard to the handling of calls through a comprehensive tandem system. Limited forms of tandem operation are possible through judicious choice of the numbering plan, and in fact such arrangements are extensively used in the Los Angeles network. The following, however, will indicate the nature of the problem of handling calls through a centralized tandem office such as was indicated in Figure 2.

Assume that the subscriber is calling a distant office reached through tandem and has dialed the office code digits of the number. These digits have controlled directly the various selectors and have caused the call to arrive at a selector level as indicated in Figure 6. The selector level is connected to a trunk terminating on tandem-office switches which must be supplied with the digits required

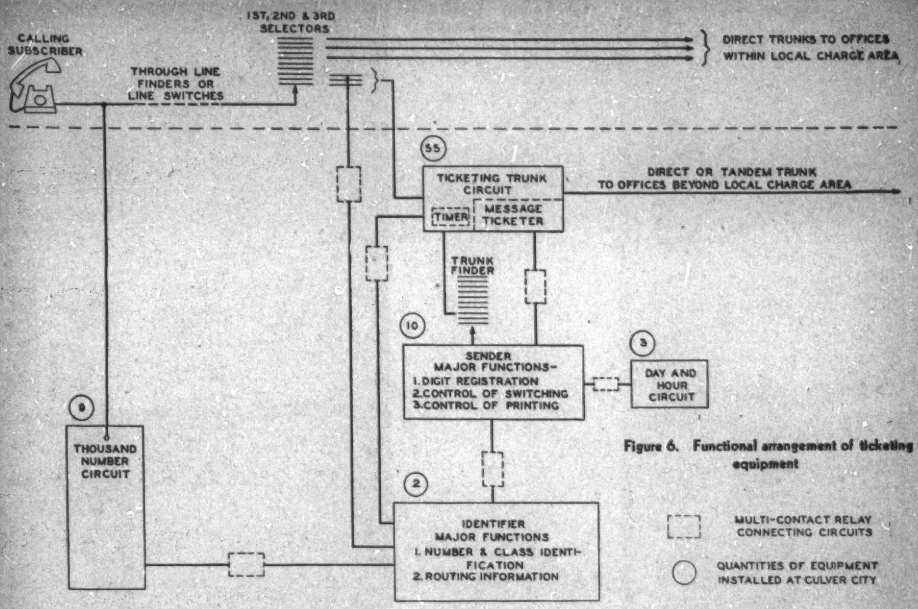


Figure 6. Functional arrangement of ticketing equipment

for directing the call to the terminating office; but these are the digits that already have been used up in the selectors of the originating office. The equipment associated with the ticketing trunks must, therefore, be capable of reconstructing these digits, meanwhile storing the additional digits being dialed by the subscriber and repeating them after the call has been extended to the terminating office.

It should be noted further that, in the originating office, the traffic to the terminating office we are considering is combined with the traffic to numerous other terminating offices over the common group of tandem trunks and that accordingly a given ticketing trunk may be reached from a number of selector levels. The equipment, therefore, has the problem of ascertaining the selector level over which a given call has reached the trunk,

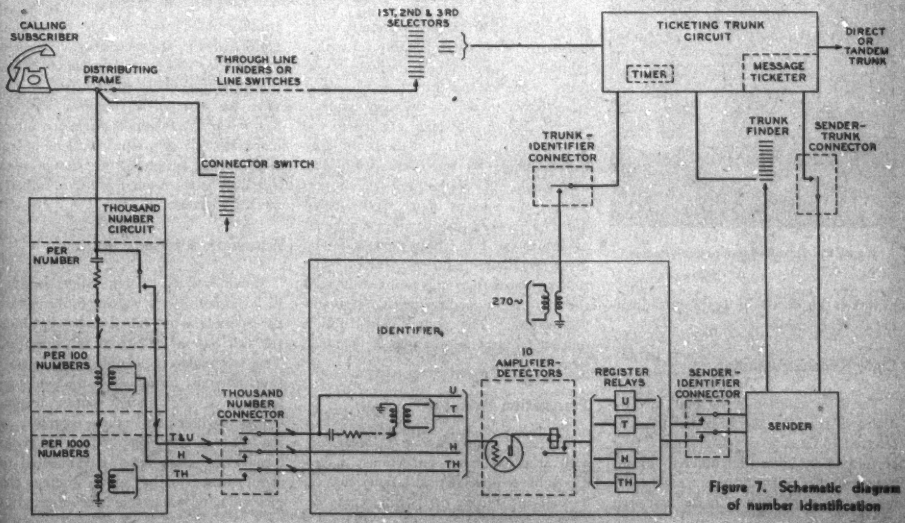


Figure 7. Schematic diagram of number identification

Figure 8. Ticketing trunk-circuit frames

Figure 9 (right). Sender frame (capacity three senders)

as well as the office code digits corresponding to that selector level.

Code Reconstruction

The determination of the digits already dialed in reaching the ticketing trunk is referred to as code reconstruction. It is performed by somewhat different means than number identification, partly for reasons of speed, since it is the first step in completion of the call. Details being omitted, the identifier is equipped with a number of "route relays," which it presents to the various entrances of the ticketing trunk by way of the relay connecting circuit. A d-c signal applied to the trunk causes operation of the route relay corresponding to the entrance in use. The route relay carries contacts representing the various digits of the called office code, which can be cross-connected arbitrarily so that these digits may be given any desired numerical values. The routing information thus supplied through the route relay operates register relays in the sender. The code reconstruction process requires approximately one-half second.

Translation Features

The use of route relays in the identifier, with arbitrary cross-connections, makes it possible to provide translation; that is, to send out routing digits which may be entirely different from the office code digits dialed by the subscriber. However, in areas for which this equipment is designed, it is generally unnecessary to provide the equipment required for full flexibility. Provision is made for direct trunking, full or partial tandem operation, and the automatic insertion of voice repeaters at the tandem office on calls requiring their use.

Automatic Alternate Routing

It will be noted that the sender receives its information as to routing of the call on the basis of the individual path over which the call has arrived from the selectors. This fact makes it possible to route calls from different terminals of the same selector level over different routes; for example, the first two or three terminals of the selector level representing a given terminating office may be connected to direct trunks to that office, whereas the succeeding terminals may be connected to

trunks to tandem. Calls which find the direct trunks busy therefore will overflow into the tandem trunks. The equipment will provide in each case the appropriate routing for reaching the same terminating office. This process is known as automatic alternate routing. It affords material economy in the design of the trunk plant because it permits provision of a small number of direct trunks used at high efficiency and combines the overflow traffic with that to other offices over the common tandem trunk group, also used at good efficiency.

Nonticketed Calls

There are cases where economy in trunk plant can be gained by taking advantage of the trunking features of the ticketing equipment and routing through it certain calls dialed by subscribers or operators for which no ticket need be printed. The equipment is arranged, under control of the class indication, to omit the ticket on such calls, and if the call is from a message-rate subscriber, to cause operation of the message register instead. Trunk circuits which omit the message ticketer entirely may be provided where economical.

Equipment Arrangements

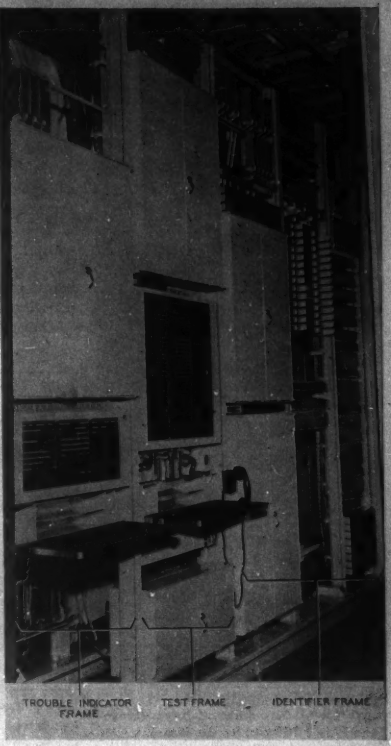
Except for the message ticketer and an arrangement to facilitate cross-connection changes in the thousand-number circuit, the ticketing system employs no essentially new types of apparatus. The relatively complicated functions are performed by suitable interconnection of relays, small electromechanical switches, vacuum-tube circuits, and other apparatus of the types commonly employed in dial switching systems.

The frames carrying the ticketing trunk equipment are arranged to bring the five ticketers of the frame together at a convenient height as shown in Figure 8. Figures 9, 10, and 11, respectively, show photographs of sender frames, an identifier frame with the adjacent test and trouble indicator frames referred to later, and a group of thousand-number frames, as installed at Culver City.

Maintenance Features

The sender and identifier circuits are of considerably greater complexity than have heretofore been used in step-by-step switching systems. A test circuit accordingly is provided, capable of verifying numerous features for routine tests or for locating indicated trouble. In addition, there is provided a "trouble indicator" patterned after that used in the crossbar switching system. It includes a panel with numerous lamps indicating various stages of the progress of the call. It is brought into play when irregularities are detected in the operation of the ticketing circuits, and the record remains even though the second trial features may cause the call to be completed satisfactorily. The information assists the maintenance force in clearing out minor troubles before they become serious and major troubles with minimum reaction on service.

Figure 10. Trouble-indicator frame, test frame, and identifier frame



General Design Considerations

With the foregoing description of the equipment in mind, some of the general considerations entering into its design may be pointed out.

In providing direct dialing to the more distant points of a metropolitan area, consideration was given to the automatic ticketing method in comparison with another method known as zone registration. This plan, which has been used to some extent in other dial systems, consists in operating the subscriber's message register more than once on completion of a call to a distant zone in accordance with the rate schedule, and on overtime calls to operate it further for each overtime interval. One important consideration in the Los Angeles area, however, was that the percentage of subscribers having flat-rate local service is relatively high, particularly in the suburbs, and for these subscribers it would have been necessary to add message registers used only for recording the multiunit calls. In addition, there were circuit problems in arranging the existing registers for repeated operation. Aside from technical considerations the individual record provided by the automatic ticketing method has commercial advantages which increase in importance as the distance, and consequently the charge for the call, increase.

The ticketing system has been described on the basis that a subscriber,

Figure 11. Thousand-number frames (capacity 2,000 numbers per frame)

calling from anywhere in the metropolitan area, will dial the number as listed in the directory to reach any other subscriber in the area. This arrangement, known as a universal numbering plan, has been adopted as the ultimate plan for exchanges included in the Los Angeles metropolitan area, now embracing some 975,000 telephones. This plan, in combination with automatic ticketing, will give the subscriber a uniform method of dialing his calls, as distinguished from the use of directing codes to be prefixed to the number on calls between different exchanges of the area.

The choice of a numbering plan for any area is, however, a telephone problem in itself, and it only need be pointed out here that the ticketing arrangement has capabilities for being used under various plans. Its use on calls between different cities, in cases where the traffic may be sufficient to warrant, would require, in general, some form of directing codes and suitable instructions to subscribers. The ticketing plan can be adapted to such arrangements as further experience may show to be desirable.

Ease of application to existing offices was a primary factor in design. At Los Angeles all the city offices have been converted to dial operation as have also the majority of the suburbs. The ticketing equipment can be added to offices having

Figure 12. Ticket arranged for photoelectric scanning

either line finders or line switches with only minor modifications of a few of the existing circuits.

The technical problems of handling ticketed calls are in many ways similar to those encountered in handling traffic in large metropolitan areas in which crossbar equipment is now used.[3] The techniques employed in the ticketing system have taken advantage of the developments and experience gained with the crossbar system. Some of these techniques may be pointed out.

The concentration of complicated functions in a few common circuits has various advantages but requires high-speed operation and special safeguards. High speed is obtained by the use of simple quick-acting apparatus, chiefly relays of ordinary telephone types, and the liberal use of wires for interconnection between circuits within the building. Connection is made through multicontact relays which are carefully interlocked.

Various safeguards are built into the circuits for detecting irregularities. To illustrate, registration of a digit which may have any numerical value from zero to nine is commonly done over a group of five wires with combinations of two closures out of five. The receiving relays are arranged so that if fewer or more than two closures are received, as may occur in case of contact failure or a wiring cross, the condition is instantly recognized. Where possible, the circuit makes a second trial, using other paths if available. In any case the irregularity is registered on the trouble indicator as an aid in preventive maintenance.

Mechanical Accounting

The design of the system provides for future application of mechanical methods to the accounting processes. A possible method is to arrange the ticketer so that, in addition to the digits which it now prints, it will print also their equivalents in code marks which can be recognized by photoelectric scanning. A ticket so arranged is shown in Figure 12.

Other forms of record produced by different types of recording mechanisms may be found advantageous, and the equipment for use at the accounting center may be designed to mechanize the accounting processes to any degree found economical.

Conclusion

Further application of ticketing equipment will, of course, have to await the end of the war. In the meantime the limited installation which the Southern California Telephone Company has been able to make at Culver City will provide useful experience and a basis for further development in this phase of the telephone art.

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Fusing Practices on Distribution Systems

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DISCUSSION of fusing practices on distribution systems with numerous operating engineers gives the impression that there are almost as many practices as there are operating companies. To determine present fusing practices in this country, a questionnaire was submitted to some 200 operating companies, and replies were received from 168, indicating a real interest in this subject. The data presented here apply only to systems operating below five kilovolts and were obtained from companies located in all parts of the country. All fuse link data are given on the basis of *N* rated links. The small amount of data which was received involving 65 per cent rated links has been converted to equivalent *N* rating. No attempt is made to weigh the data by taking into consideration the size of the operating company, as it is the intention to show engineering thought on the subject.

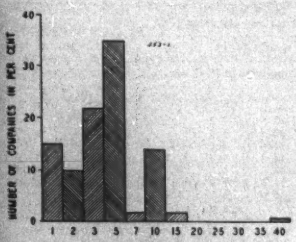

Figure 1. Minimum fuse rating employed by 167 companies

100 per cent = 167 companies

Distribution-Transformer Fusing

In order better to understand the data obtained from the questionnaire, the first question asked was, "Why do you fuse distribution transformers?" The replies show that 80 per cent of the companies fuse to protect the system from the transformer, 59 per cent fuse to protect the transformer, 17 per cent use fuses to indicate the location of faults, and 16 per cent use them as an isolating means. While a number of companies gave only one reason for fusing transformers, others gave two or more. Thus, as these percentages are based on the number of companies, the total will be more than 100 per cent.

The enclosed indicating cutout is preferred by 70 per cent of the companies for fusing the primary circuits of distribution transformers. The enclosed nonindicating cutout is preferred by 22 per cent of the companies, whereas only 8 per cent expressed a preference for the open type. The majority of operators prefer the enclosed cutout at this voltage for safety considerations. Because of the relatively close conductor spacing and pole-top congestion it is almost impossible for linesmen to avoid contact with live parts. For this reason it is common practice to insulate as much of the equipment and as many conductors as is practical. The marked preference for the indicating cutout is more difficult to explain, as in the majority of applications there is no fundamental need for the indicator. The most reliable indication of a blown fuse is the telephone of an affected customer. However, the indicating cutout has the advantage of removing the organic material from across the gap left by the blown fuse, thus eliminating trouble caused by leakage currents across the fuse tube.

The development of repeating fused cutouts naturally raises the question as to their use in conjunction with distribution transformers. Most companies use only single-shot fuses on their distribution transformers because of their lower cost and the fact that almost all internal transformer faults are of a permanent nature. Repeating fused cutouts are used with distribution transformers to a limited extent, however, by eight per cent of the companies.

Table I. Operating Companies Using Various Combinations of Transformer and Fuse Ratings

2,400 Volts Single-Phase or 4,160 Volts Three-Phase Wye
100 Per Cent = 144 Companies

Single-Phase Transformer Rating—Kva (Multiply by 3 for Bank Kva)	Fuse Link Ratings—Amperes														
	1	2	3	5	7	10	15	20	25	30	40	50	65	85	100
	Number of Companies in Per Cent														
1.5	4	1	22	8	18	7	35	0	1	6	15	4	2	4	
3			2	1	44	8	33	8	2	1	13	8	3	4	
5					3	3	64	5	4	6	21	7	5	9	
7.5						0	7	9	4	25	4	53	6	8	1
10							1	5	1	5	70	4	20	6	3
15								2	6		11	8	67	1	11
25										4	0	8	0	18	9
37.5											1	4	2	8	4
50												1	4	0	7

Single-Phase Transformer Rating—Kva (Multiply by 3 for Bank Kva)	Fuse Link Ratings—Amperes														
	1	2	3	5	7	10	15	20	25	30	40	50	65	85	100
	Number of Companies in Per Cent														
1.5															
3															
5															
7.5															
10															
15												0	7		
25												2	7		
37.5												2	7	0	7
50												3	1	0	7

Because of the wide variations in systems and in the locations of fused cutouts it is difficult to apply them so as to keep within their published interrupting ratings. It is interesting to note that exactly 50 per cent of the companies apply cutouts at locations where the calculated

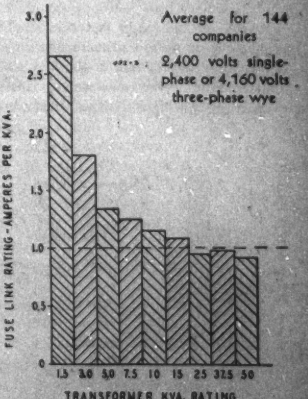

Figure 2. Weighted average of Table I—operating companies using various combinations of transformer and fuse ratings

Paper 44-52, recommended by the AIEE committee on power transmission and distribution for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted November 13, 1943; made available for printing December 14, 1943.

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Table II. Operating Companies Using Various Combinations of Transformer and Fuse Ratings

2,400-Volt Three-Phase Delta
100 Per Cent = 58 Companies

Single-Phase Transformer Rating—Kva (Multiply by 3 for Bank Kva)	Fuse Link Rating—Amperes														
	3	5	7	10	15	20	25	30	40	50	65	85	100	150	200
	Number of Companies in Per Cent														
5	1.6	21.0	11.3	61.3	4.8										
10		8.3		13.3	31.7	26.7	15.0	3.3	1.7						
15		1.5		14.7	11.8	19.1	32.4	13.2	7.3						
25				6.3	8.0		12.7	6.3	38.1	25.4	3.2				
37.5						7.1	3.6	5.4	1.8	7.1	35.7	14.3	25.0		
50							7.4	5.6	1.8	14.8	13.0	25.9	31.5		
75									8.5	8.5		10.5	59.6	12.8	
100										8.2	2.0	8.2	42.9	32.7	6.0

tions of transformer and fuse ratings. The highest percentage value is in boldface type for each transformer rating. This table applies to 2,400-volt single-phase or 4,160-volt three-phase star systems. It is interesting to note that the old rule of "one ampere per kilovolt-ampere" is followed rather closely throughout the table except in the case of the smaller transformers. Here the rule has been dropped in favor of a higher fusing ratio because of the factors mentioned in connection with the selection of the minimum fuse rating. A weighted average of the table has been plotted in Figure 2. This figure brings out clearly the fact that the smaller transformers,

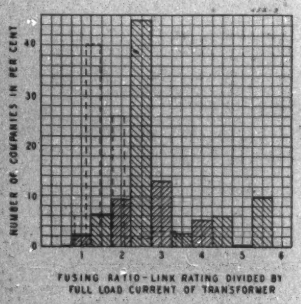

Figure 3. Weighted average fusing ratio for all ratings of transformers plotted from data of Table I

100 per cent = 144 companies

Table III. Operating Companies Using Various Combinations of Transformer and Fuse Ratings

4,800-Volt Single-Phase
100 Per Cent = 22 Companies

Single-Phase Transformer Rating—Kva	Fuse Link Rating—Amperes										
	1	2	3	5	7	10	15	20	25	30	40
	Number of Companies in Per Cent										
1.5	4.7	4.7	4.7	57.2	4.7	24.0					
3		9.1	9.1	50.0	4.5	22.8	4.5				
5			18.2	50.0	4.5	22.8	4.5				
7.5			4.5	45.5		41.0	4.5	4.5			
10			4.3	47.9		43.5	4.3				
15				9.1	13.6	68.3	4.5			4.5	
25						24.0	57.2	9.4	4.7		4.7
37.5						10.0	15.0	30.0	45.0		
50							5.0	20.0	50.0	10.0	15.0

short-circuit currents are above their ratings.

Transformer Fuse Ratings

In general the major factor in determining the rating of a primary fuse for a distribution transformer is the kilovolt-ampere rating of the transformer. However, in the case of small transformers, up to five kilovolt-amperes or even larger, other factors usually control the fuse rating. The question was asked as to the minimum-size fuse link used on the system and the factors determining it. Lightning, transformer rating, and mechanical strength were the factors most frequently mentioned. The practice as to the minimum fuse rating employed is shown in Figure 1. The range of values is even wider than can be justified by variations in local conditions and indicates a lack of consistent practice.

Table I gives the percentage of operating companies using the various combinations of transformer and fuse ratings. The highest percentage value is in boldface type for each transformer rating. This table applies to 2,400-volt single-phase or 4,160-volt three-phase star systems. It is interesting to note that the old rule of "one ampere per kilovolt-ampere" is followed rather closely throughout the table except in the case of the smaller transformers. Here the rule has been dropped in favor of a higher fusing ratio because of the factors mentioned in connection with the selection of the minimum fuse rating. A weighted average of the table has been plotted in Figure 2. This figure brings out clearly the fact that the smaller transformers, particularly the 1.5 and 3 kva, are fused much higher than the larger ones.

The weighted average fusing ratio for all ratings of transformers has been plotted from the data of Table I and is shown in Figure 3. The ratio of the minimum melting point of the fuse link to the full-load current of the transformer will be twice that shown in the figure, as all these data are based on *N* rated links. Similar data gathered about ten years ago are plotted in dotted lines. Comparing the data of the present questionnaire with the previous data indicates a desirable trend toward higher fusing of

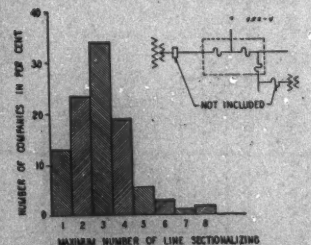

Figure 4. Line-sectionalizing practice employed by 123 companies

100 per cent = 123 companies

Table IV. Operating Companies Using Various Combinations of Transformer and Fuse Ratings

4,800-Volt Three-Phase Delta
100 Per Cent = 13 Companies

Single-Phase Transformer Rating—Kva (Multiply by 3 for Bank Kva)	Fuse Link Rating—Amperes													
	3	5	7	10	15	20	25	30	40	50	65	85	100	150
	Number of Companies in Per Cent													
5	7.2	50.0		42.8										
10		28.6		57.1		14.3								
15		7.2	21.4	21.4	28.6	21.4								
25				22.2	22.2		44.5		11.1					
37.5				8.3	8.3		41.8	8.3	25.0	8.3				
50					7.7	7.7	15.4	15.4	30.7	15.4				
75							11.1	11.1	11.1	44.5			11.1	11.1
100								6.7	13.3	20.0		33.3	20.0	6.7

A Short-Cut Method of Estimating Telephone-Influence Factor of Power Systems With Rectifier Load

C. W. FRICK
ASSOCIATE AIEE

This paper describes a short-cut method of estimating the voltage and current *TIF* at the point where the rectifier is supplied, eliminating most of the steps just described by the use of curves based on average values of the factors involved. The method assumes that the supply system has an inductive reactance at harmonic frequencies, and the effect of resonance was neglected. The method does not give results that are close enough to justify its use in place of the detailed method where a thorough study is necessary, but, in most cases where it has been tried, it has given values that are near enough to test values to be representative, as will be shown later. In a complete study of an inductive co-ordination problem it may be desirable to estimate the voltage *TIF* and *I·T* product at points on the power system remote from the rectifier location, and the method described herein is not generally suitable for this purpose, except where the power system is relatively simple. In more complicated cases the use of the more detailed methods is suggested.

The method has been set up so that it can be applied to rectifiers with various numbers of phases, including 6, 12, 24, and up to 72 phases. The trend toward larger numbers of phases for the larger rectifier installations[3,4] may be seen from Figure 1 which represents some recent rectifier installations with a combined rating of over 2,000,000 kw. This group does not include all of the large

IN the planning of rectifier installations it is often desired to study the effect of the rectifier on co-ordination with communication systems. The telephone-influence factor[1] (*TIF*) is used in such studies as an index to the effect of distortion of the voltage and current-wave shapes on the inductive influence. Both voltage and current *TIF* are involved, because there are two types of induction:

1. Electric induction which depends upon the power-circuit voltage.

2. Magnetic induction which depends upon the current.

The current *TIF* is usually multiplied by the current in amperes, and the product is designated by *I·T*. In some cases of existing exposures, neither the voltage *TIF* nor the *I·T* product is significant, and the inductive effects in such exposures are negligible. In other cases one or the other or both factors are significant in connection with existing exposures, as illustrated by Table I.

The study of rectifier circuits and power-system characteristics at harmonic frequencies has made it possible to obtain fairly good estimates of voltage and current *TIF* with rectifier operation, but the usual process is rather lengthy. This involves the calculation of system impedance for at least eight harmonic frequencies,[2] the harmonic analysis of the rectifier current wave[3,4] to obtain these eight or more harmonics, the weighting and summation of harmonic currents to get current *TIF*, the calculation of harmonic voltages from the values of current and of system impedance, and the weighting and summation of harmonic voltages to get the voltage *TIF*.

Paper 44-14, recommended by the AIEE committees on communication and power transmission and distribution for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted October 25, 1943; made available for printing December 6, 1943.

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distribution transformers. The old data which were given in terms of the 65 per cent rated fuse links has been converted to the present *N* rated links, and this explains the reduction in the width of the bars. One factor probably contributing to the increased fusing ratio is the change in method of rating fuse links. This automatically would increase the fusing ratio if the use of the same link ratings were continued.

Since the information contained in Table I applies to the majority of distribution systems, it has been given graphically in other forms in Figures 2 and 3 to bring out trends and factors which are not readily apparent from a table. Similar data are given in Tables II, III, and IV for other systems and are subject to the same treatment.

All companies replying use primary fused cutouts. Figure 3 shows the fusing ratios to be such, in most cases, that low-impedance secondary faults near the transformers will be cleared by the primary fuses. It is not surprising therefore, to find that only 12 per cent of the companies use fuses in secondary leads of some of their distribution transformers.

Line Sectionalizing

The questionnaire revealed that 85 per cent of the companies use cutouts for line sectionalizing. Of these, 54 per cent use them on the main feeders, 76 per cent on the three-phase branch feeders, and 83 per cent on single-phase laterals. The repeating cutout is most popular on the main feeders where 50 per cent are of this type, as contrasted with 41 per cent on the three-phase branches and 37.5 per cent on the single-phase laterals. About 70 per cent of the cutouts used for line sectionalizing, regardless of their location, are of the enclosed indicating type. Beyond the agreement that line sectionalizing is desirable, however, there is very little uniformity of practice. This is illustrated in Figure 4 where the maximum number of line-sectionalizing fuses employed in series, between the source interrupter and the distribution-transformer fuse, varies from one to eight. In those cases where the use of seven and eight fuses in series was indicated, it is probable that the source interrupter and the transformer fuse were included. If this is true, these cases should appear in the bars for five and six fuses.

A large amount of material can be found in the technical literature dealing with this subject, and much of it is of real value. It is recognized that this is a problem to which the most satisfactory solution can be found only by combining operating experience with theoretical analysis. The data included in this paper indicate that much of the present fusing practice is based principally upon operating experience without sufficient engineering interpretation. Further study of this problem should result ultimately in better system performance with fewer ratings and simpler devices.

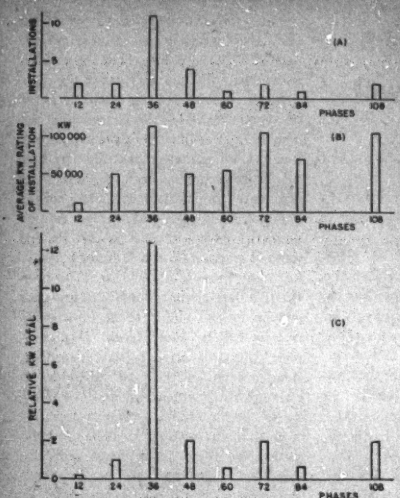

Figure 1 (left). Phase arrangements used in 26 rectifier installations, 10,000 kw and larger

A. Number of installations using each phase arrangement

B. Average kilowatt rating of installations for each phase arrangement

C. Relative total kilowatts for each phase arrangement

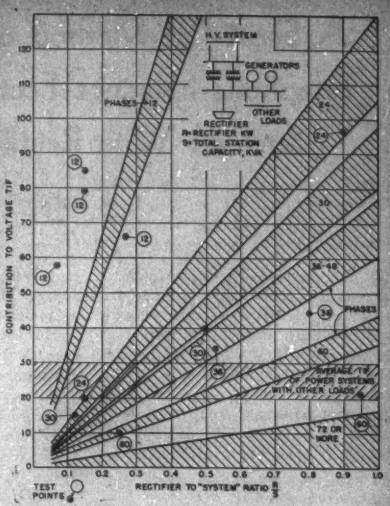

Figure 2. Curves for estimating voltage *TIF*, 60-cycle systems with rectifier load, 12 or more phases

Some of the test points were taken with the *TIF* meter in common use which is based on the 1919 weighting network (see reference 1). Figures in circles opposite test points show number of rectifier phases

installations but is believed to be representative of installations in service or under construction. Most of these installations are 36 phase, and the average installation rating for 36 phases is about 100,000 kw. It may be noted also that there are some installations with 72 or more phases.

This paper deals only with the *TIF* and does not consider other factors that are significant to inductive co-ordination. Some of the other factors are discussed in reports on the subject.[2,7]

The method described here is applicable to a-c systems and not applicable to d-c systems which are supplied by rectifiers. The treatment of the d-c case by methods already in use[3,7] is usually a fairly simple procedure.

Description of Short-Cut Method

This method of estimating voltage *TIF* makes use of a factor designated here as the rectifier to supply ratio R/S, because voltage *TIF* depends on the relative power capacities of rectifier and source. In the case of a rectifier supplied directly from a generating station, this is the ratio of the rectifier kilowatt rating to the combined generator kilovolt-ampere rating. When this ratio is used, the *TIF* is read directly from a curve sheet, such as that shown in Figure 2.

The curves were calculated by assuming a supply station of a certain kilovolt-ampere and voltage, having a reactance of ten per cent referred to the fundamental frequency, on the rated kilovolt-amperes and supplying a rectifier of average characteristics. A range of rectifier kilowatt ratings was assumed, extending from one tenth of the supply-station rating up to the full station rating (ratios of R/S from 0.1 to 1.0). This includes some conditions which were used for calculations but may not apply in practice to all of the phase arrangements covered; for instance, a generating station would not be loaded with 6- or 12-phase rectifiers up to its full capacity. The rectifier current was analyzed on a percentage basis by the methods available.[2,4] Harmonic currents in amperes were obtained by assuming equal values of rectifier and power-station ratings ($R/S=1.0$) for the initial calculation. These currents were multiplied by the station reactance, based on the ten per cent figure, to obtain the harmonic voltages on the station bus. These harmonic voltages were weighted and combined by the root-sum-square rule to obtain the *TIF* which was plotted at $R/S=1.0$ on Figure 2. This *TIF* value would come out the same for any assumed kilovolt-amperes and voltage, because the harmonic currents and the reactance were obtained on a percentage basis. For values of the ratio R/S less than 1.0 the rectifier operates at its own full load, and the percentage harmonic currents would be the same. Starting with the same station kilovolt-amperes, the reactance would be the same, but the currents in amperes would be proportional to the ratio R/S. Hence, the *TIF* would be reduced in proportion to R/S and could be represented by a straight line, as in Figure 2. This neglects the effect of station reactance on the current-wave shape which is unimportant in these approximate estimates.

Calculations were made for each num-

Table I. Significance of Various Influence Factors in Existing Exposures

Case	Type of Circuit: Power	Type of Circuit: Communication	Significant Factor: Exposure to Main Rectifier Feeder	Significant Factor: Exposure to Branch Line
A	Cable	Either open wire or cable	Inductive effects generally negligible	
B	Overhead lines	Cable (toll)	Inductive effects generally negligible	
C	Overhead lines	Cable (local)	*I·T*†	*V-TIF** in some cases
D	Overhead lines	Open wire	*V-TIF* and *I·T*	*V-TIF*

* *V-TIF* Voltage *TIF*. † *I·T* Product of current times *TIF*.
This table is based on Table 6 of the Edison Electric Institute report.[7]

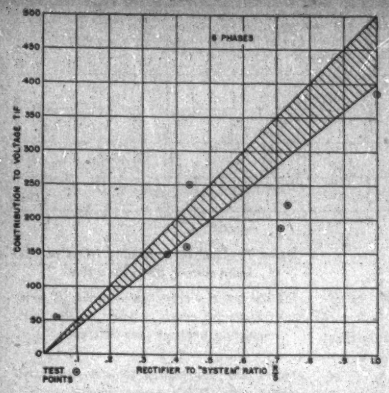

Figure 3. Curves for estimating voltage *TIF*, 60-cycle systems with rectifier load, six phases

The test points were taken with *TIF* meter in common use which is based on the 1919 weighting network (see reference 1)

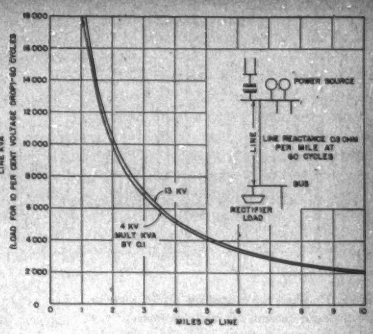
LINE KVA (LOAD FOR 10 PER CENT VOLTAGE DROP-60 CYCLES)
MILES OF LINE
13 KV
4 KV MULT KVA BY 0.1
POWER SOURCE
LINE
LINE REACTANCE 0.8 OHM PER MILE AT 60 CYCLES
BUS
RECTIFIER LOAD

Figure 4 (right). Curves for estimating line kilovolt-amperes for *R/S* ratio of Figures 2 and 3

ber of phases, and a curve was plotted. It may be noted that the curves of Figure 2 are drawn as zones which cover a range from about ten per cent above to ten per cent below the calculated *TIF* values. This implies that estimates made from the curves are not expected to be closer than ten per cent, even if the simplifying assumptions which have been made are valid in the case under consideration. If the conditions differ materially from those assumed in preparing the curves, or if resonance between elements of the supply system is an important factor, the estimates may differ from the actual results by much more than ten per cent.

Voltage TIF of 60-Cycle Systems

The curves of Figures 2 and 3 apply to 60-cycle systems and cover all of the common phase arrangements. The *TIF* values are based on the 1935 weighting curve.[1] Estimates of *TIF* are made in the following manner: When the rectifier is close to the supply station, the rectifier-to-supply ratio *R/S* is obtained by dividing the rectifier kilowatt rating by the total kilovolt-amperes of the station. The estimated voltage *TIF* at the station is read from the point on the curve sheet corresponding to *R/S* and the number of phases. This is the contribution of the rectifier of the total *TIF*. Sometimes it may be desirable to state that the estimated *TIF* is between the two values indicated by the zone. The procedure just described applies to rectifier load close to a generating station, a substation tied in with a larger power system, or a station which combines these two conditions, in which case the combined kilovolt-ampere rating of generators and transformers which feed into the same bus is used. The procedure for rectifier load at some distance from the source is described in a paragraph which follows. The curves are based on ten per cent reactance referred to 60 cycles. Allowance for other per cent reactance values can be made, as illustrated in one of the examples given later (see example 1).

The total *TIF* of the station-bus voltage may be estimated by taking the square root of the sum of the squares of the rectifier contribution and the system *TIF* without the rectifier. If the system *TIF* is not known, an average value may be estimated from Figure 2.

When the rectifier is at some distance from the supply station, the line reactance may be the determining factor for the voltage *TIF* at the rectifier. The curves of Figures 2 and 3 may be applied to this case by using line kilovolt-ampere instead of station kilovolt-amperes. This is the kilovolt-ampere load which would produce a reactive voltage in the line equal to ten per cent of the line voltage at 60 cycles. Figure 4 gives curves for lines up to ten miles long at 4 kv and 13 kv, from which values of line kilovolt-ampere can be obtained. For other voltages the kilovolt-ampere value may be obtained by reading the kilovolt-amperes from one of the curves and multiplying by the square of the ratio of actual kilovolts to kilovolts on curve. Also, for other lengths of line the kilovolt-amperes may be read for an assumed length and multiplied by the ratio of the assumed length to the actual length. After the *R/S* ratio has been obtained, the curve is used

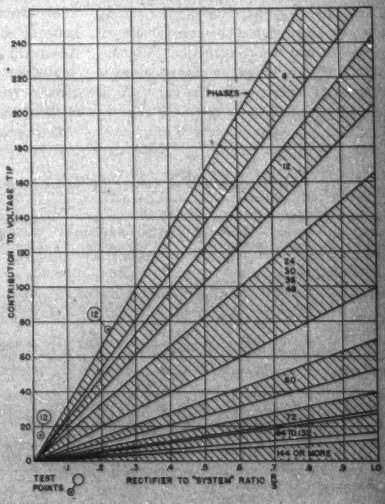

Figure 5. Curves for estimating voltage *TIF*, 25-cycle systems with rectifier load

The test points were taken with the *TIF* meter in common use which is based on the 1919 weighting network (see reference 1). Figures in circles opposite test points show number of rectifier phases

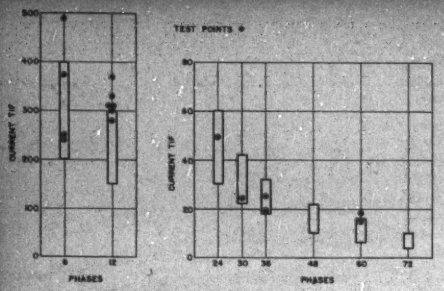

Figure 6. Chart for estimating *TIF* of rectifier input current, 60-cycle systems

Some of the test points were taken with the *TIF* meter in common use which is based on the 1919 weighting network

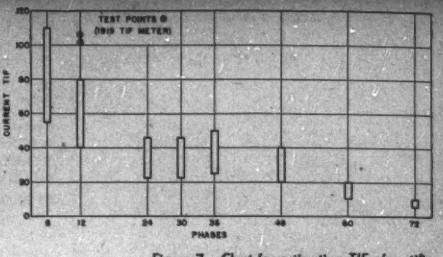

Figure 7. Chart for estimating *TIF* of rectifier input current, 25-cycle systems

The test points were taken with the *TIF* meter in common use which is based on the 1919 weighting network (see reference 1)

as already described. Sometimes both the line and the station reactances are determining factors. In such cases a value of kilovolt-amperes is determined which gives ten per cent reactive voltage in the line and station combined. This can be shown best by means of an example given later (see example 4).

The curves were calculated on the basis of inductive reactance. In power systems with cable circuits or extensive overhead lines, capacitance is a factor. In some cases resonance occurs at certain harmonic frequencies which may increase or decrease the voltage *TIF*. The method described here does not allow for resonance. The more detailed methods provide for taking resonance into account when necessary, but some approximations are involved.

Some rectifier installations have provision for adjustment of the output voltage by means of phase control (or grid control). If the range of adjustment is small, *TIF* values from the curves will be close enough in most cases. If the adjustment by phase control is over five per cent, the voltage *TIF* may be increased in the order of 2 to 1. One of the references[3] gives some limited test data on this point, and another[6] gives some calculations on effects of phase control.

The available measured values of *TIF* have been plotted on Figures 2 and 3 for comparison with the curves. Most of these values have been published.[3,7] A majority of the 19 test points are within or reasonably close to the proper zones. The points farthest from the curve are three points for the 12-phase rectifiers where the measured values are 1.6 to 2 times the values from the curves. These tests were made on overhead systems, where resonance conditions existed, and increases of this order would be expected.

Voltage TIF of 25-Cycle Systems

The curves of Figure 5 apply to 25-cycle systems and correspond to those of Figures 2 and 3 for 60-cycle systems. They were calculated on the basis of ten per cent reactance referred to 25 cycles. When the voltage *TIF* is to be calculated at a rectifier which is at some distance from the supply station, values of line kilovolt-amperes may be obtained from Figure 4, which is for 60 cycles, and multiplied by 2.4, the ratio of 60 to 25. This conversion is necessary, because reactance voltage is proportional to frequency. The available *TIF* measurements on 25-cycle systems have been plotted on Figure 5, and their agreement with the curves is comparable with the 60-cycle data.

Current TIF of 60-Cycle Systems

The charts in Figure 6 give approximate values of current *TIF*, based on the 1935 weighting curve, for rectifiers on 60-cycle systems. The same phase arrangements are covered, as in Figures 2 and 3, for voltage *TIF*. The shaded areas allow for the spread between different circuit conditions. The estimated *I·T* product is obtained by multiplying the rectifier current in amperes, in the a-c line supplying the rectifier, by the *TIF* from the chart. The available test data from the sources referred to under voltage *TIF* have been plotted on the charts for comparison with the calculated values. Reasonable agreement is shown in most cases. Phase control may increase the current *TIF* when the voltage adjustment is more than five per cent.[3,8]

Current TIF of 25-Cycle Systems

The charts in Figure 7 give approximate values of current *TIF* for rectifiers on 25-cycle systems. They correspond

Table II. Estimates of Voltage *TIF* for the Conditions of Example 3

Rectifier (Kilowatts)	Number of 24-Phase Units	Phase Arrangement	Combination Assumed for Calculation (Values of R)	Generating Station Kilovolt-Amperes (S)	R / S	TIF Component for Each Group	TIF for Combination
40,000	2	24	24-phase $R = 40,000$	80,000	0.5		60
40,000	2	48	48-phase $R = 40,000$	80,000	0.5		35*
60,000	3	48 and 24	48-phase $R = 60,000$	80,000	0.75	53	60
			24-phase $R = 20,000$		0.25	28	
60,000	3	72	72-phase $R = 60,000$	80,000	0.75		13*
80,000	4	48	48-phase $R = 80,000$	160,000	0.5		35
80,000	4	72 and 24	72-phase $R = 80,000$	160,000	0.5	13	20*
			24-phase $R = 20,000$		0.125	15	
100,000	5	72 and 24	72-phase $R = 100,000$	160,000	0.63	10	30*
			24-phase $R = 40,000$		0.25	28	
100,000	5	48 and 24	48-phase $R = 100,000$	160,000	0.63	45	55
			24-phase $R = 20,000$		0.125	33	
120,000	6	48	48-phase $R = 120,000$	160,000	0.75		55
120,000	6	72	72-phase $R = 120,000$	160,000	0.75		13*

* Arrangements for minimum *TIF*.

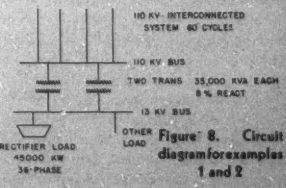
110 KV. INTERCONNECTED SYSTEM 60 CYCLES
110 KV BUS
TWO TRANS 35,000 KVA EACH 8% REACT
13 KV BUS
OTHER LOAD
RECTIFIER LOAD 45000 KW 36-PHASE

Figure 8. Circuit diagram for examples 1 and 2

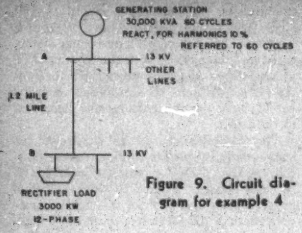

Figure 9. Circuit diagram for example 4

In a test on a 36-phase rectifier, where the rectifier kilowatts and the station-transformer kilovolt-amperes were in the same ratio as in this example, the measured *TIF* was 34 as compared with the calculated value of 39.

EXAMPLE 2

The voltage *TIF* on the 13-kv bus of example 1 is to be estimated with one sixth of the rectifier plant shut down. This is one of the six six-phase groups of which the 36-phase installation is composed. The 36-phase connection suppresses all of the six-phase harmonics up to the 35th and 37th. The vector sum of five units is therefore equal in magnitude to one unit for these harmonics. The 35th and 37th harmonics, however, are all in phase. If it is assumed that the full load is being carried by the five units, the combination will be treated as a 36-phase rectifier of the total rating and a superimposed 6-phase rectifier of one fifth of the total capacity.

For the 36-phase component

$$\frac{R}{S}=\frac{45{,}000}{87{,}500}=0.52$$

$TIF=36$ from Figure 2

For the six-phase component

$$\frac{R}{S}=\frac{1}{5}\times\frac{45{,}000}{87{,}500}=0.1$$

$TIF=40$

Total rectifier contribution to *TIF*

$$=\sqrt{36^2\times 40^2}=54$$

Over-all *TIF* at bus $=\sqrt{54^2+15^2}=56$

If the six-phase group is removed, the *TIF* thus increases from 39 (example 1) to 56.

In the test referred to in example 1 the measured *TIF* with one six-phase unit shut down and the other five carrying the station load, was 61. This is slightly higher than the calculated value of 56, possibly because phase control was being used to some small extent to equalize the division of load between the rectifier units.

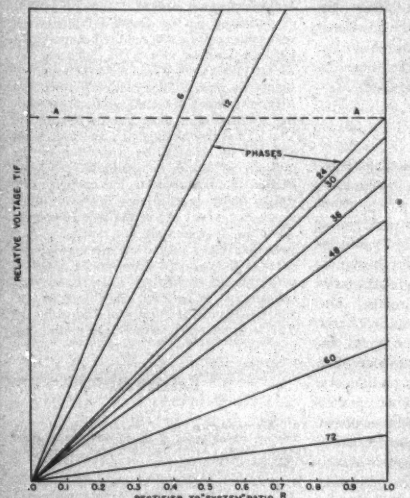

Figure 10 (left). Tentative curves for estimating voltage *TIF* with proposed weighting curve, 60-cycle systems with rectifier load. For ordinates see Figure 12

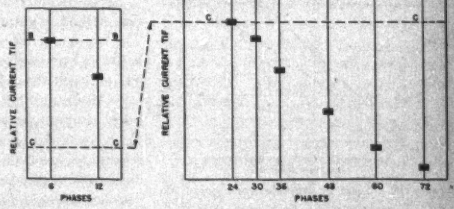

Figure 11 (right). Tentative chart for estimating current *TIF* with proposed weighting curve, 60-cycle systems with rectifier load. For ordinates see Figure 12

EXAMPLE 3

In a preliminary study of a proposed rectifier installation, it is desired to estimate the effect of several combinations of rectifier units and phase arrangements. Each unit is 20,000 kw, 24 phase. The initial installation is to be 40,000 kw (two units) supplied from a station of 80,000-kva capacity. A third unit is to be added later. Still later the generating station is to be increased to 160,000 kva and three more units added, one at a time. The frequency is 60 cycles. Since the generator reactance is not known, it is assumed to be ten per cent for harmonics.

Several combinations of 24, 48, and 72 phases might be used. Combinations, such as two units combined to give 48 phases and one additional 24-phase unit, are treated as follows. Since the 47th and 49th harmonic components are additive, a 48-phase rectifier of the full kilowatt rating (the combined rating of three units) is assumed and its *TIF* contribution taken from Figure 2. The additional contribution of the 24-phase unit is controlled mainly by the 23rd and 25th harmonics, and its value is taken from Figure 2 for the rating of the 24-phase unit. The two components are combined as the square root of the sum of the squares. The calculations and the results are shown in Table II.

The preferable combinations from the standpoint of obtaining as low *TIF* values as possible are indicated by the asterisk. These combinations are 48

to those of Figure 6 for 60-cycle systems. The available test data for 25-cycle systems are indicated by test points.

Illustrative Examples

The examples which follow are given for the purpose of showing how the data in this paper might be applied to specific rectifier situations.

EXAMPLE 1

It is desired to estimate the voltage *TIF* on the 13-kv bus of the station shown in Figure 8 which supplies 45,000-kw rectifier load, 36 phase. The system *TIF* without rectifier load is 15.

The station capacity is 70,000 kva with eight per cent reactance. Since the curves are based on ten per cent reactance, we use $70{,}000\times 10/8=87{,}500$ kva. Then $R/S=45{,}000/87{,}500=0.52$. With reference to Figure 2, the *TIF* for 36 phases corresponding to $R/S=0.52$ is between 32 and 40, or about 36. The over-all *TIF* at the bus is $\sqrt{36^2+15^2}=39$.

phase for two units (initial installation), 72 phase when the third unit is added, 72 phase and 24 phase with four and five units, and finally 72 phase for the whole installation of six units. The conversion from 48 to 72 phase when the third unit is installed could be provided for in the beginning by furnishing phase-shifting transformers with suitable taps to reduce the phase displacement.

EXAMPLE 4

With reference to Figure 9, it is desired to estimate the voltage *TIF* at the station bus *A*, the rectifier bus *B*, and the *I·T* product for the rectifier feeder *AB*. The rectifier rating is 3,000 kw, 12 phases, and the generating-station rating is 30,000 kva. The rectifier feeder is 1.2 miles long.

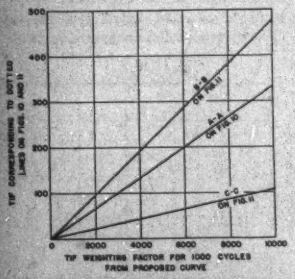

Figure 12. Scale of ordinates for Figures 10 and 11 corresponding to various proposed scales for new *TIF* weighting curve

To estimate the *TIF* at the station bus *A*, the ratio $R/S = 3{,}000/30{,}000 = 0.1$ is used. If we refer to Figure 2, the *TIF* is about 30.

To estimate the *TIF* at point *B*, the following calculation is made:

line kilovolt-amperes = 17,500 for 1.2 mile line (from Figure 4)
station kilovolt-ampere = 30,000
total kilovolt-amperes for *S* at ten per cent is then

$$\frac{17{,}500 \times 30{,}000}{47{,}500} = 11{,}000$$

$$\frac{R}{S} = \frac{3{,}000}{11{,}000} = 0.27$$

With reference to the curve for 12-phase rectifiers in Figure 2 the *TIF* is approximately 80.

To estimate the *I·T* product for the feeder, the current *TIF* is about 225, from Figure 6. The line current is

$$I = \frac{3{,}000}{1.73 \times 13} = 133 \text{ amperes}$$

Then

$I \cdot T = 133 \times 225 = 30{,}000$ approximately

In a test where the ratio of rectifier kilowatts to station kilovolt-amperes and the ratio of line reactance to generating-station reactance were about the same as in this example, the measured *TIF* at the rectifier was 65. Also, the measured *I·T* referred to 13 kv, since the line voltage was different, was 42,000.

Conclusion

Herein is described a practical short-cut method of estimating power-system *TIF* at a rectifier supply point. It is based on previously demonstrated methods of calculating harmonics produced by rectifiers together with certain simplifying assumptions as to the characteristics of rectifier and power circuits. The results are reasonably consistent with test data. The method should be useful, especially where a number of conditions have to be investigated in a preliminary study, since it requires only a few minutes to make the calculations for each condition when the pertinent data are at hand. The results may be useful also for checking other calculations. The method is applicable to the arrangements of 24 or more phases that are being used for large rectifier installations as well as to the 6- and 12-phase arrangements used for the smaller stations. In a co-ordination study the *TIF* has to be considered in combination with other factors, such as the type and location of circuits. This is pointed out in the introduction.

Appendix

Recent tests on telephone equipment have resulted in a new frequency weighting curve for message circuit noise.[3] A proposed *TIF* weighting curve based upon these data has been agreed upon as to shape. The magnitude of the peak or other ordinate has not been decided upon yet. The next step in the program is to make studies of electric apparatus and systems with the object of arriving at the weighting curve of this shape which will give the best correlation between data taken with new type instrument and data taken with the existing *TIF* meter. This appendix gives data to show the effect which the proposed revision would have on the calculations described in the paper.

The establishing of the shape of the curve made it possible to plot curves showing relative *TIF* for various numbers of rectifier phases. Figure 10 shows a set of curves of voltage *TIF* for 60-cycle systems with rectifier load which is similar to Figure 2 for the 1935 weighting curve, but the ordinates are not marked. However, a scale of ordinates can be drawn for any given weighting curve of the required shape in the following manner: First, the weighting factor for 1,000 cycles is read from the proposed weighting curve. Then reference is made to Figure 12 which gives the *TIF* corresponding to the dotted line *AA* on Figure 10. The *TIF* corresponding to any other ordinate can be obtained by proportion, or the ordinate scale can be graduated suitably. Figure 11 shows charts for current *TIF* similar to those of Figure 6 for the 1935 weighting curve. As in the case of voltage *TIF*, the ordinates are not marked. *TIF* values corresponding to any given weighting curve of the required shape can be obtained with the aid of Figure 12 as already described. It is believed that these curves will be helpful in studies of the proposed *TIF* with reference to rectifier installations.

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The Functions of Ground Preference in Carrier-Current Relay Schemes

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ALMOST all of the more common present-day carrier relay systems employ a feature known as ground preference which enables the ground relays, during faults involving ground current, to take preference over the phase relays in controlling the starting and stopping of the carrier signal. The specific system conditions which require this feature are not well understood, nor is it generally understood that under certain conditions ground preference can cause trouble, or that even in some cases phase preference is "preferable." It is the purpose of this paper to discuss, in general, the reasons for and conditions pertaining to the preference feature.

The most common type of carrier relay system now in general use is the intermittent carrier system employing distance-type relays to control carrier, carrier being transmitted only in the unfaulted line sections to block tripping. There are two variations of this scheme; one using a three-zone impedance relay to start and stop carrier by circuit-closing contacts, and another using a three-zone reactance relay to start carrier by a circuit-opening contact and to stop carrier by a circuit-closing contact. These two arrangements are shown in Figure 1 in only enough detail to illustrate how the preference feature is obtained. The circuit-closing arrangement is shown in Figure 1a. Closure of the phase or ground start contacts connects the cathode of the master oscillator tube to battery negative, which is the condition for oscillation; and opening of the stop contacts returns the grid to the nonoscillating condition. The phase start contact is operated by a fault-detector impedance element and the phase stop contact is operated by an element whose coil is energized by a second impedance element whose contacts are in series with the single-phase directional-element contacts. The ground start contact is operated by an overcurrent element with a low current setting while the ground stop contact is operated by an auxiliary element energized from an overcurrent element with a high setting, whose contact is in series with the ground directional contact. It is evident from this diagram that the ground relays can start and stop carrier regardless of the position of the phase contacts. Also it is clear that a phase preference could be obtained by interchanging the position of the phase and ground start and stop contacts and that no preference is obtained by paralleling the phase and ground start contacts. Figure 1b shows the schematic connections for the reactance-relay carrier system. Carrier is started by opening any one of the voltage-restrained fault-detector contacts, thus removing the carrier control lead from battery negative which is the carrier-transmission condition. Carrier can then be stopped by the closure of the phase stop contact which is operated by a single-phase voltage-restrained directional element. Carrier is started on ground faults by the opening of the ground start contact on a low-set overcurrent relay and is stopped by the closure of a high-set overcurrent contact and a directional contact. It is clear that the ground relays have preference in controlling over the phase relays. Also, phase preference or no preference can be obtained by the proper regrouping of the contacts.

There are a number of system conditions presented to the relays during faults involving ground current which may cause failure to block through carrier unless steps are taken to prevent such action. The ground-preference feature is one of these steps. Fundamentally, the trouble results from the fact that during single-phase-to-ground faults, and especially during two-phase-to-ground faults, both the phase and ground relays respond. It is possible that, under certain conditions, the ground relays will see an external fault as such, whereas the phase relays may view the situation as an internal fault. On the other hand, under certain other conditions, the phase relays may view the situation correctly, but the ground relays may not see the correct picture.

An example where the phase relays may see a fault as internal, whereas it is an external fault, correctly seen by the ground relays, is the case where the current fed through a line section to an external fault is mostly zero sequence. Figure 2 depicts a condition of this kind which has been made extreme for simplification. For a single-phase-to-ground fault on the line out of substation D, power is fed from station B to the grounding bank at A, and zero-sequence fault current is fed over all three phase wires in the line section C—D to the fault as is shown by the solid arrows. A power source at E would feed current over only one phase wire in the line from C to D.

While the conditions shown are not typical, in that a grounding bank has its power source at another point in the system, the conditions on any grounded system will approach the aforementioned conditions. That is, any transmission line between a source of power and a grounding point will carry in-phase fault currents on all three phase wires. The application of carrier relays to the line section C–D requires consideration of this fact. An examination of the action of single-phase directional elements reveals that under the aforementioned conditions the carrier signal at D is liable to be removed incorrectly by one of the phase relays. Since carrier is removed correctly at C by the ground relay, failure to block on the external fault results. It is evident that if star currents are used on the phase directional relays the three single-phase directional elements at D cannot all indicate the same direction since the currents in all three are inphase but the voltages are considerably out of phase.

As will be easily seen from Figure 3,

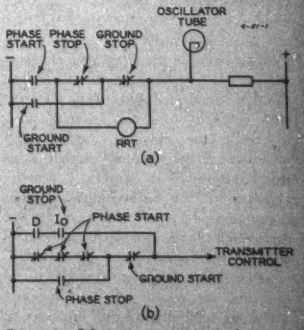

Figure 1. Schematic connections of ground-preference arrangement

Paper 44-51, recommended by the AIEE committee on protective devices for presentation at the AIEE winter technical meeting, New York, N. Y., January 24–28, 1944. Manuscript submitted November 18, 1943; made available for printing December 14, 1943.

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which depicts the voltages and currents applied to the relays at location D, directional elements with a watt characteristic and a 30 degree connection, for example, will indicate both directions. That is, the A-phase element using I_A current and E_{CA} voltage will open contacts for a close in external fault; also the B-phase element will open contacts and the C-phase element will close contacts.

In view of the foregoing it can be stated that any type of single-phase directional element used for the purpose of controlling carrier will cause failure to block tripping for external ground faults under one or another of the conditions met with on a grounded power system.

The preceding is discussed on the basis that star current is used on the directional element. However, a carrier system using single-phase watt-type directional elements energized from delta current gives a different answer. It is evident that the delta connection of currents (Figure 4a), wherein the A-phase element receives I_A-I_B, the B-phase element receives I_B-I_C and the C-phase elements receive I_C-I_A, completely cancels out the three inphase zero-sequence currents represented by the solid arrows, and the directional elements receive no fault current. However, the delta-connected directional elements will respond to load current, and, if, while the external ground fault in Figure 2 exists, load current flows from station D to station C, carrier blocking will not be accomplished since the ground directional relay at C removes carrier and the phase directional elements at D also remove carrier.

As far as the aforementioned directional elements are concerned, the incorrect action in removing carrier on external ground faults can be eliminated by the use of a ground-preference connection such as shown in Figure 1. There it is obvious that the incorrect indication of the phase directional elements on ground faults is of no concern since the ground relays can start and stop carrier regardless of the phase relays. The facts brought out in the foregoing yield some pertinent observations. If star currents are used in the phase directional elements the ground-preference feature definitely is needed, since the elements give false directional indications because of the flow of zero-sequence fault currents. Furthermore, the incorrect indication of the directional relay on zero-sequence fault current is augmented by the flow of load current in the opposite direction. In other words, load current flowing from station D to C on phase C adds more or less in-phase to the zero-sequence fault current from station C.

Phase directional relays using delta currents require the ground-preference feature only because of the possible flow of load current opposite to the zero-sequence fault current.

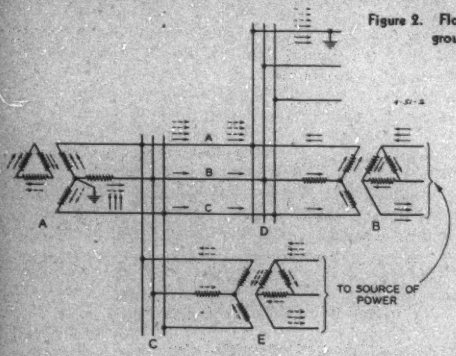

Figure 2. Flow of fault current on a grounded system

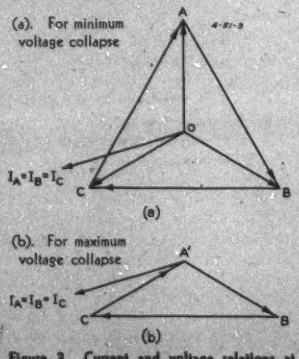

Figure 3. Current and voltage relations at station D

So far, consideration has been given only to the zero-sequence fault current from the grounding bank A as represented on Figure 2 by the solid arrows. On any actual power system, however, there may be a flow of positive-, negative-, and zero-sequence current from another source of power such as the transformer bank E. The line currents flowing from bank E to the fault are shown by the dotted arrows. Note that the bank E fault-current contribution in section C–D flows only in the faulted phase A. It is interesting to see what effect this current has in connection with the use of the ground-preference feature. When star current is being utilized, it is quite evident that the directional response of the three directional elements is not at all changed, since the additional phase-A current merely supplies more opening torque to the phase-A element and does not affect the incorrectly responding phase-C element.

On the other hand when the directional elements are supplied with delta current, the fault current on phase A from bank E causes the A-phase and C-phase directional elements to open contacts. This is seen from Figure 4b where I_A (representing current flow toward station D) with E_{CA}' and $I_C=-I_A$ with E_{BC} give opening torque. The flow of 100 per cent-power-factor load current from station D to C is represented by the star currents inside the triangle $CA'B$, and it is seen that the load current on phase C is substantially opposite to the fault current I_C. This means that the phase-C directional element cannot operate in the wrong direction unless the load current

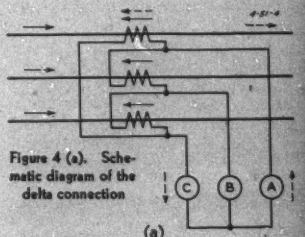

Figure 4 (a). Schematic diagram of the delta connection

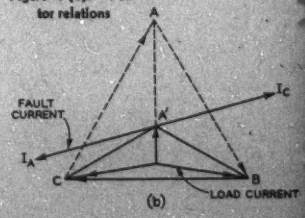

Figure 4 (b). Vector relations

predominates over the phase-*A* fault current which is supplied by the bank *E*. However, fault current does not appear in the phase-*B* relay, and, therefore, its directional element may close contacts because of load current.

Heretofore, only the directional element has been discussed. However, present day distance-relay carrier systems employ a distance-measuring element to supervise the directional element. In one system a separate impedance element *Z2* has its contacts in series with the directional element to stop carrier and complete the trip circuit through the receiver relay contacts. Another system uses voltage restraint on the directional element to accomplish the same purpose effectively.

It is now necessary to see how the use of the supervising distance element affects the requirement for ground preference. If the case where the directional elements receive delta current are considered first, the impedance elements would also receive this same current, and the effect of the impedance element is as follows: If all of the fault current from *C* to *D* is zero-sequence current, the relay at *D* is subject only to load current, and it can stop incorrectly carrier transmission for load current flowing from *D* to *C* only if this load current is high enough to reach the pickup point of the impedance element at the voltage existent during the fault. For an external ground fault on phase *A*, for instance, the voltage on *A*-phase and *C*-phase impedance elements may be anything between the limits of normal for a distant fault to 58 per cent of normal for a close-in fault. In order to close the phase-*B* relay contacts the load current would have to operate against full normal voltage. Ordinarily, the setting of the supervisory impedance element would be considerably above the maximum load current.

When the additional fault current flowing on phase *A* only is considered, the conditions for incorrect operation of the relays at station *D* became even more difficult to attain. As was seen previously, the fault current on phase *A* causes the *C*-phase relay to act correctly and counteracts the effect of the load current. The only condition where phase-*C* relay could indicate the wrong direction would be for the load current from *D* to *C* to be larger than the fault current on phase *A*. A slightly predominant load current could reverse the phase-*C* directional contacts, but in order to operate the supervising impedance element the predominance would have to be considerably greater than this to reach the pickup of the impedance element whose voltage is greater than 58 per cent of normal. The action of the phase-*B* relay must also be considered even though, as is seen from Figure 4a, it receives no fault current. However, there is load current in phase -*B* relay, but to get incorrect action out of this relay, the load from *D* to *C* must reach the pickup of the impedance element which has full normal voltage, and, of course, this is impossible.

In the case where star current is used, the addition of the distance-measuring element to supervise the directional element does not lessen materially the chances for incorrect operation. As was shown previously, the zero-sequence fault current on phase *C* may be of sufficient magnitude to operate the distance element since the restraint voltage may be reduced to 58 per cent of normal. Furthermore, this element may also be subject to zero-sequence fault current plus load current, and under these conditions it is quite possible that the phase-*C* relay will try to remove carrier.

The fault current from bank *E*, Figure 2, which flows only on phase *A* would, of course, have no effect on the phase-*C* relay.

The preceding considerations lead to these conclusions:

1. If the phase directional and distance supervising elements use star current, then ground preference definitely is needed to prevent incorrect removal of carrier on single-phase-to-ground faults because of the flow of zero-sequence fault current on the unfaulted phases and also because this current adds to the load current flowing in the opposite direction.

2. If delta current is used, then ground preference is required only if the through-fault current is all zero-sequence current and the load current in the opposite direction is large enough to reach the pickup value of the supervising impedance element at 58 per cent of normal voltage. Such a set of conditions is comparatively rare, and, therefore, if delta current is used, ground preference can be eliminated in order to take care of other conditions if necessary.

While, heretofore, the ground-preference arrangement has been used in most carrier installations with good results, it nevertheless has, upon occasions, been desirable to have some other form of preference. One instance where the ground-preference connection causes trouble is the case of a two-phase-to-ground fault involving a high ground resistance. Here the ground current may be between the pickup values of the ground-tripping overcurrent element and the ground carrier start overcurrent element, in which case carrier is put on by the ground relays but not taken off, thus blocking the phase relays from high-speed tripping, and the fault must be cleared by time-delay backup action. This undesirable action can be, and actually has been, eliminated by removing the overcurrent element from the carrier stop circuit and making the removal of carrier by the ground relays dependent only upon the ground directional relay. This, of course, requires that the sensitivity of the ground directional relay be the same as that of the overcurrent carrier start relay. However, the sensitivity of the carrier stop element cannot be made too great, otherwise failure to block will result on external phase faults where system unbalances may produce enough spurious ground current to cause the sensitive ground-carrier stop element to operate.

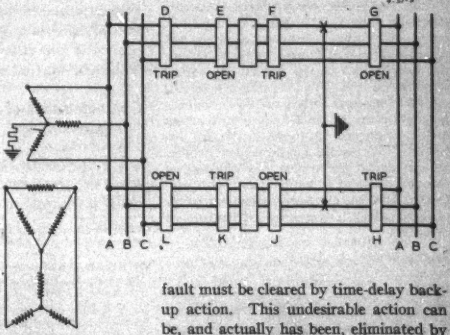

Figure 5. Schematic diagram of system requiring phase preference

While the ground-preference connections have been used extensively in carrier relay system, heretofore, it should be realized that there are certain system conditions which require phase-relay preference rather than ground preference. A specific instance where phase preference is required is the case of simultaneous ground faults in different line sections.

Influence of Improved Magnetic Alloys on Design Trends of Electrical Instruments

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Synopsis: Small panel-type electrical indicating instruments are recognized as an important component in radio, electronic, and power control equipment, which is so essential in all military and naval operations on land, in the air, and on the sea. Such instruments are required to be small, compact, light in weight, and reliable measuring devices; and one of the major factors in the realization of these requirements is the efficient utilization of improved magnetic materials for permanent magnets.

This paper describes properties of a new magnetic alloy and compares its characteristics with other permanent-magnet materials used in small panel electrical indicating instruments of the permanent-magnet moving-coil type. The use of a new cobalt-molybdenum-iron alloy as a permanent magnet material in an indicating instrument and its influence on design trends are discussed. The resulting improvement in overall instrument performance by the use of this new material is summarized, with particular reference given to mechanical factor of merit which is a measure of instrument reliability.

THE use of new and improved permanent-magnet alloys which have been developed during recent years probably has influenced the design trend of electrical indicating instruments more than any other one factor. For given sensitivities, instruments have been made available which are more sturdy and reliable, and instruments of higher sensitivity have been made possible by the use of the newer alloys. Relatively higher coercive force *Hc* and high residual *Br* materials are now available that are readily machined and use a minimum of critical materials, factors which are of particular importance in high production designs for wartime applications.

Characteristics of Permanent-Magnet Alloys

The properties of 11 commercially available permanent-magnet alloys recently published[1] are shown in Table I.

Paper 44-31, recommended by the AIEE committee on instruments and measurements for presentation at the AIEE winter technical meeting, New York, N. Y., January 24–8, 1944. Manuscript submitted November 10, 1943; made available for printing December 3, 1943.

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Until comparatively recently, the chrome and tungsten alloy steels were the principal materials used for permanent magnets in electrical indicating instruments, replacing the unalloyed carbon steels previously used. These alloys possess fair machining qualities and can be fabricated by either hot-forging or punching into various sizes and shapes, but they are inherently low in available energy and require a relatively large ratio of length of magnet to length of air gap. Magnets from these materials are frequently manufactured from preshaped rods or bars, cut to length, heated, and formed to the required shapes while hot by the use of special equipment. After cooling, subsequent grinding, drilling, and machining operations are performed, after which they are hardened and the air gap accurately ground. A typical finished magnet is shown in Figure 1A.

Soft-iron pole pieces are then used to provide the correct flux distribution and to insure permanency of the flux pattern. Figure 1B shows a typical magnet and pole-piece assembly.

Low coercive forces *Hc* in the order of 60 to 70, residual flux density *Br* of 9,000 to 10,300 gausses, and total relative energy of 295,000 to 320,000 (*BH* maximum energy) are typical values for the magnetic characteristics of these alloys.

Some magnets which are used for small panel-type instruments are made from these materials in the form of laminations of thicknesses of approximately one sixteenth of an inch punched from sheet material to final shape in conventional dies and stacked to desired height after hard-

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On systems grounded through an impedance it sometimes happens that a flashover to ground on one phase may immediately cause another flashover on another phase in another line section. Analysis of the action of directional ground relays under these conditions shows that the directional indication at several locations may be incorrect. The situation is depicted schematically in Figure 5, and it is seen that, for a ground fault on phase *A* in section *FG* and on phase *B* in section *JH*, one ground relay in each section except *DE* as indicated by "open" and "trip" operates incorrectly. If carrier relaying with ground preference were applied to this system, incorrect operation would result in both faulted sections. In section *FG* the phase relays at *F* would remove carrier but would be blocked by carrier from *G* which is held on by the ground relay. (Blocking of carrier transmission by the fault is an exception). In section *JH* the same action would occur. If the carrier connections were changed to give preference to neither the ground relays nor the phase relays, then correct tripping would occur in the faulted sections because the phase relays would clear the faults. However, carrier blocking would not be obtained in section *LK*, since the phase relays would remove carrier at *L* and the ground relays would remove it at *K*. If preference were given to the phase relays, correct action in all sections would result, since the phase-relay directional indications are correct, and the distance elements easily can be set to respond to this type of fault.

Conclusions

1. The necessity for the ground-preference feature in carrier relay systems depends, to a large extent, on the type of current connections used in the phase relays.

2. When star currents are used in the phase relays, the ground preference feature definitely is needed during the flow of fault current and load current.

3. If delta currents are used in the phase relays, the ground-preference feature is needed only in cases where the fault current is all zero sequence and extreme load currents are present.

4. Phase preference is required on systems subject to simultaneous grounds in different line sections, and if delta currents are used the phase-preference connection is feasible.

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1. A NEW HIGH-SPEED DISTANCE-TYPE CARRIER-PILOT RELAY SYSTEM, E. L. Harder, B. E. Lenehan, S. L. Goldsborough. AIEE TRANSACTIONS, volume 57, 1938, January section, pages 5–10.

2. SUGGESTIONS FOR AVOIDING FAULTY ACTION OF GROUND RELAYS, Roy M. Smith. *Electrical World*, May 1930, pages 1092–5.

Table I. Properties of Commercial Permanent-Magnet Alloys

	Alloy	Typical Composition (Per Cent)	Coercive Force (Hc)	Residual Induction (Br)	B×H (Maximum)	Mechanical Properties	Commercial Methods of Fabrication
1.	Chromium magnet steel	3.5 Cr; 1 C; remainder, Fe	63	9,000	295,000	Hard and strong	Hot forge, punch and machine
2.	Tungsten magnet steel	5 W; 1 C; remainder, Fe	70	10,300	320,000	Hard and strong	Hot forge, punch cast, machine
3.	Cobalt (36 per cent) magnet steel	36 Co; 3.5 Cr; 1 C; remainder, Fe	210	9,000	930,000	Hard and strong	Hot forge, punch cast, machine
4.	Cobalt–nickel–copper alloy	41 Co; 24 Ni; 35 Cu	440	5,300	993,000	Ductile	Cold-roll, machine, punch cast
5.	Iron–nickel–copper alloy	20 Fe; 20 Ni; 60 Cu	450	5,300	1,070,000	Ductile	Cold-roll, machine punch
6.	Comol magnet alloy	12 Co; 17 Mo; remainder, Fe	245	10,300	1,100,000	Hard and strong	Hot forge, punch machine, cast
7.	Alnico IV	12 Al; 28 Ni; 5 Co; remainder, Fe	700	5,200	1,250,000	Hard and brittle	Cast, sinter, or grind
8.	Alnico III	12 Al; 25 Ni; remainder, Fe	400	7,100	1,330,000	Hard and brittle	Cast, sinter, or grind
9.	Alnico I	12 Al; 20 Ni; 5 Co; remainder, Fe	400	7,100	1,330,000	Hard and brittle	Cast, sinter, or grind
10.	Alnico II	10 Al; 17 Ni; 12.5 Co; 6 Cu; remainder, Fe	540	7,200	1,650,000	Hard and brittle	Cast, sinter, or grind
11.	Alnico V	8 Al; 14 Ni; 24 Co; 3 Cu; remainder, Fe	525	12,000	4,000,000	Hard and brittle	Cast, grind

ening and finishing. Warpage during heat treatment, variations in dimensions, and changes in the value and distribution of the flux are sources of difficulty in this type of magnet. A magnet of this construction is shown in Figure 1C. While this type of magnet design affords low cost, the strength is usually somewhat less than that obtained with the solid magnet construction.

With this construction soft-iron pole pieces, although not always used, are desirable to insure permanence of the flux pattern in the armature gap, since any changes in flux pattern may affect the instrument accuracy.

From a mechanical standpoint, it is usually more difficult with built-up construction to maintain accurate and permanent alignment and relationship of the various parts of the element assembly than with the solid magnet construction.

Increased sensitivities of instruments were made possible by the use of cobalt alloy steels as permanent magnets. Pierre Weiss of Zurich, Switzerland, investigated this material in 1912, and it was later reduced to practice by P. H. Brace of the United States and Honda of Japan in an alloy having about three times the coercive force H and about equal to the residual B found in the chromium and tungsten steel alloys. For the past 15 to 20 years, this material has been used in instruments, providing a means of producing higher sensitivities. It has been used in forged and cast forms and is most attractive from the standpoint of high coercive force H of about 210 with total energy (BH maximum) of 900,000 but its inherent high cost limits its use primarily to the higher-sensitivity instruments where the chrome and tungsten steels are unsatisfactory.

The foregoing materials are all steels which require quenching in oil or water at high temperatures in order to develop properly their magnetic qualities.

Further phenomenal advances have been made in recent years in strength of permanent-magnet materials by the development of the aluminum-nickel-cobalt iron (Alnico) alloys which are of particular interest to the electrical-instrument designer because of their high values of coercive force and available energy as shown in Table I. These materials are characterized in electrical-instrument design by their relatively large cross section and short lengths of magnetic section to air-gap ratio, as has been previously shown,[3] and are highly resistant to demagnetizing fields because of their high coercive force Hc. While the Alnico materials have been used widely as instrument magnets, their manufacture is restricted to only two methods, namely, sintered process, and casting and grinding. The first process is usually restricted to relatively small designs sometimes found ideal for damping magnets and the like, as shown in Figure 2, while the second process is used for the production of the majority of Alnico magnets.

Cobalt–Molybdenum–Iron Alloys As Applied to D-C Instruments

The ideal magnet from the standpoint of the instrument designer would be one having high coercive force, residual induction, and available energy, and which had good machining and fabricating qualities. While a material of this type

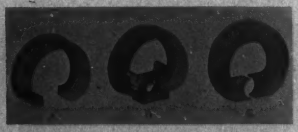


Figure 1. Forms of chrome-steel magnets

A. Formed and machined
B. Pole pieces added
C. Laminated construction

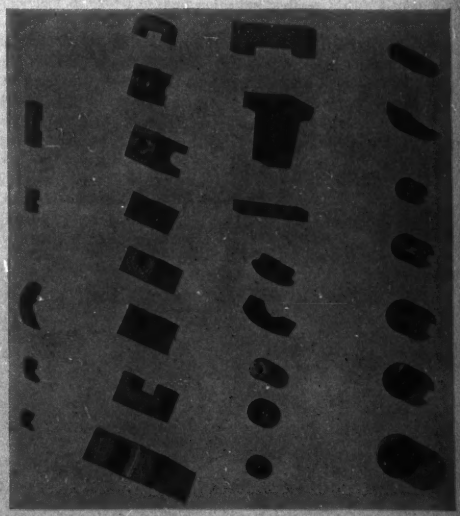


Figure 2. Sintered Alnico magnets

having magnetic characteristics equal to those of the Alnico group is not commercially available, an approach has been made in the cobalt-molybdenum-iron alloys more commonly known as Comol, as covered in Dean reissued United States patent 20800.

With the advent of Comol (typical composition: 12 per cent cobalt, 17 per cent molybdenum, remainder iron) a new material was made available which contains a minimum of the critical metals, such as cobalt, which could be cast easily and, when properly heat-treated, could be drilled, milled, and machined readily

Figure 3. Small panel indicating instrument utilizing cast Comol magnet

by conventional methods. As a result, accurate machining dimensions permit the degree of precision which is required to utilize this material fully in instrument magnets.

A coercive force *Hc* of about 245 is obtained as compared with 210 for 36 per cent cobalt with a residual induction *Br* of 10,300, higher than either 36 per cent cobalt or Alnico II, and a maximum energy value of 1,100,000 as compared with 930,000 for 36 per cent cobalt and 1,650,000 for Alnico II.

A modification of the Comol magnet material described heretofore but containing appreciably lower percentage of the critical elements has been utilized for the first time in instrument application as the permanent magnet in a new "thin" line of d-c and radio-frequency General Electric small panel permanent-magnet-moving-coil-type instruments as shown in Figure 3.

In view of the fact that very little information regarding the application of the newer permanent-magnet alloys as applied to indicating instruments is now available, it is proposed to treat this subject in some detail and to study the magnet circuit design as well as the moving system associated with it.

Permanent-magnet moving-coil d-c instruments of any conventional design contain certain essential parts as shown in Figure 4. *A* is the permanent magnet with suitably curved pole faces or with soft-iron pole pieces. *B* is a soft-iron cylindrical core centrally located with respect to the magnet pole faces or pole pieces so as to provide a uniform air gap

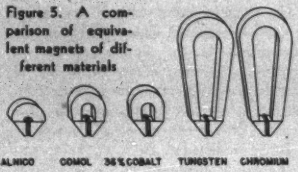


Figure 5. A comparison of equivalent magnets of different materials

in which the moving coil *C* turns upon its bearings.

The theory of operation of this type of design is well known and will be referred to only briefly at this time.

The permanent magnet *A* sets up a magnetic field in the uniform air gap, between the magnet pole faces or pole pieces and the cylindrical core *B*. The moving coil *C* is free to turn in the air gap and is equipped with two control springs, one fastened to each end of the coil, which serve to conduct the current to and from the coil and also control the pointer movement. The pointer movement is dependent upon the reaction between the flux due to the current in coil *C* and the flux due to the permanent magnet *A*. The turning moment or torque produced by the coil is directly proportional to the current passing through it assuming uniform flux density in the gap, and the opposing torque of the springs is proportional to the angle through which the armature turns, thus making the scale divisions upon which the value of current or voltage is measured, uniform.

From the preceding, it is seen that the permanent magnet is of utmost importance to the satisfactory operation of the instrument, and careful consideration should be given to its design.

The ideal condition in instrument magnet design from the standpoint of torque occurs when the magnetic energy maintained in the air gap is a maximum per unit volume of magnet steel. A comparison of ideal magnet sizes for a given strength of the more generally used magnet materials is shown in Figure 5. These ideal sizes are sometimes altered, however, to facilitate proper physical

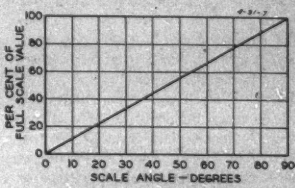


Figure 7. Typical scale distribution of indicating instrument using Comol magnet

arrangement of other instrument components.

The Manufacture of Cobalt–Molybdenum–Iron Alloy Magnets

A typical magnet of Comol material for the General Electric type *DW*51 instrument previously mentioned is shown

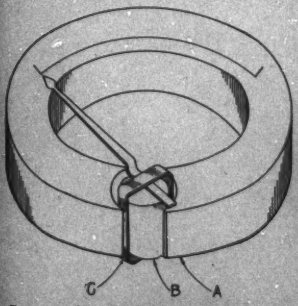


Figure 4. Basic element of permanent-magnet moving-coil instrument design

Figure 6. Forms of cast Comol magnets

A. Uniform gap
B. Diagonal pole face

Figure 8. Element assembly utilizing cast Comol magnet

Figure 9. A method of magnetizing the element assembly

in Figure 6A. In general the manufacture of these magnets is as follows:

The Comol alloy is compounded in a high-frequency induction furnace using relatively pure raw materials and remelt scrap. It is cast in baked sand molds to form the particular magnet desired. Following this, the magnets are given a soaking treatment at a temperature close to their melting point to destroy the "as-cast structure" and develop the necessary conditions to permit age hardening later in the process. At the end of this treatment they are quenched rapidly and at this stage are relatively soft and easily machined. The magnets are drilled, milled, or ground, as required, and then age-hardened to develop the full magnetic properties.

For the so-called linear-scale thermocouple instruments, the diagonal pole-face magnet is used as shown in Figure 6B, and the casting and machining operations on it follow those of the uniform-gap magnet shown in Figure 6A.

This material has shown very uniform magnetic potential along the pole face so as to make the use of soft-iron pole pieces unnecessary. An actual distribution provided by this type of magnet is shown on Figure 7. The lack of soft-iron pole pieces has led also to slight reductions in leakage flux as compared with similar magnets of other materials utilizing soft-iron pole pieces. In this particular design the element is assembled completely to the unmagnetized magnet in a manner as shown in Figure 8. Such a procedure is desirable from the instrument manufacturer's standpoint, since it affords an ideal method of positioning the parts correctly and reduces the hazard of the magnet picking up extraneous particles of dirt during handling.

Magnetizing the magnets after assembly not only provides greater flux density but allows the magnet to be magnetized without a "keeper" and with the soft-iron core in place, thus giving a uniform magnetic potential along the pole face. This method eliminates the hazard of losing magnetic strength during assembly.

The ideal method of magnet saturation has been found to be by the use of a single conductor placed through the center of the magnet as shown in Figure 9 and by passing a high current through the conductor to saturate the magnet. Experience has shown that magnets of the size described herein require the following currents for approximately full saturation:

Material	Ampere Turns Per Inch
Chrome	500
Tungsten	600
36 per cent cobalt	1,700
Comol	2,000
Alnico II	4,400

The permanency of the magnet strength after final adjustment is important to the sustained accuracy of the instrument. While this is controllable to a large measure by the casting and aging technique, all magnets are demagnetized a few per cent in strength with an a-c field in order to stabilize them further. Changes in magnet strength with time on sample groups of magnets checked under laboratory controlled conditions have been negligible.

Changes in strength due to ambient-temperature changes on magnets made of the Comol alloy mentioned heretofore is approximately −0.017 per cent per degree centigrade rise, a value which is surprisingly close to values for ambient-temperature changes found in other magnet alloys.

Application of Comol-Magnet Material to a New Moving System

The moving system used with this new magnet is of the internal-pivot construction with the supporting pivots mounted inside the armature shell, whereas the conventional armature has the pivots mounted outside; see Figure 10. This feature has been used in order to obtain a thin element, and the conventional type of moving system can be used equally well with this magnet.

The general objective of the moving system design is to obtain a light weight with as low a moment of inertia as is practical for required stability and overload requirements, in order to realize the best over-all dynamic characteristics and a high mechanical factor of merit.

The mechanical factor of merit has been recognized as the engineering yardstick as to the practicability of a design from the standpoint of magnitude, or pivot friction, or zero uncertainty and sturdiness, or ability to withstand abnormal usage for a long period of time. This factor may be termed as an index of the freedom-from-friction errors and is a function of control spring opposing torque for a given angle deflection divided by the weight of the moving system. It has been shown previously[3,4] that, for the comparison of similar instruments of good commercial design having vertical shaft and V-type bearings this relation becomes:

$$\text{Mechanical factor of merit} = T/W^{1.5}$$

where

T = spring torque in gram-millimeters for 90 degrees deflection

Table II. Constants for Typical 2½-Inch-Diameter Small Panel-Type Comol and Chrome Magnet D-C Milliammeters, Accuracy ±2 Per Cent of Full-Scale Value

		Comol	Chrome
Magnetic Circuit			
1.	Total mean magnet length (centimeters)	10.7	10.0
2.	Air-gap area (square centimeters)	0.99	1.15
3.	Air-gap flux (saturated) (maxwells)	1,980	1,495
4.	Air-gap flux density (saturated) (gausses)	2,000	1,310
5.	Torque per ampere turn K (gram-millimeters) (after adjusted)	1.38	0.905
Moving Element			
1.	Mechanical factor of merit		
	(a). For horizontal shaft (T/W)	0.486	0.318
	(b). For vertical shaft ($T/W^{1.5}$)	0.915	0.598
2.	Moment of inertia (gram-centimeter²)	0.52	0.65
3.	Damping factor (0−full-scale minimum)	9.4	3.6
4.	Response (seconds) 0−2/3 scale	1.0	1.9
5.	Ambient-temperature coefficient of magnet, per cent per degree centigrade	−0.017	−0.025
6.	Maximum errors due to five gausses External field		
	(a). Temporary error of per cent of full scale	1.0	1.0
	(b). Permanent error of per cent of full scale	Negligible	Negligible
7.	Magnet stability errors due to six cycles (four hours at −40 degrees centigrade, four hours at +75 degrees centigrade, four hours at +25 degrees centigrade)		
	(a). Maximum change in per cent of full scale	0.10	0.52
	(b). Minimum change of per cent of full scale	0.02	0.24
	(c). Average change in per cent of full scale	0.07	0.35

W = weight of moving system and one control spring, in grams

For the comparison of similar instruments having horizontal shafts, this relation becomes T/W.

In good design, an effort is made to keep these factor-of-merit values relatively high which usually means high control-spring torque. The value of spring torque, other things being constant, varies as the magnet air-gap flux density as shown by the following:

The control-spring torque in the conventional permanent-magnet moving-coil design of instrument may be found from

$$T = KNI$$

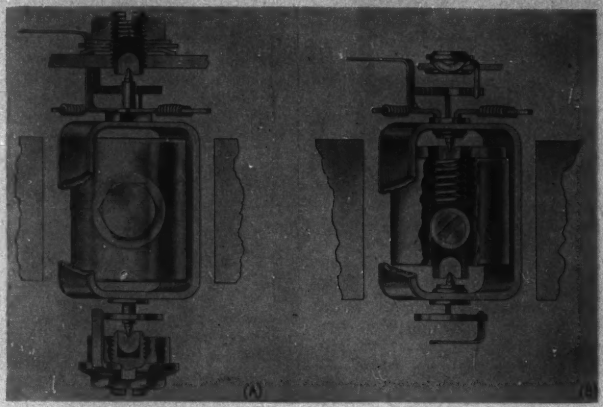
where

T = total control-spring torque in gram-millimeters for 90 degrees deflection
K = magnet constant in torque per ampere turn
N = number of turns on armature
I = current in amperes in coil

In order to keep the value of torque T as high as possible, the quantity KNI must be kept at a maximum. NI is kept as high as possible by using the maximum number of turns of wire for a given current sensitivity. Further increase in torque can be obtained only by increase in magnet strength, which makes any improvements in magnetic materials of prime importance to the instrument designer.

Consideration has to be given also to the minimum weight of the moving system. The "fixed parts" such as pointer, pivots, pivot supports, counterweight arms, and winding supports should be designed for minimum weight, but the winding will vary with sensitivity because of variation in number of turns and wire diameter used. In this particular design, the total weight of the winding will approximate twice the weight of the fixed parts for the higher-sensitivity designs and will approximate the weight of fixed parts for lower sensitivities.

A tabulation showing some of the more important constants of a typical $2^1/_2$-inch-diameter instrument using the high-coercive-force Comol cast magnet as compared with a conventional instrument of the same size using chrome steel formed magnet may be seen in Table II. The substantial increase in air-gap flux density by the use of Comol magnets provides a significant increase in the magnet constant K and the mechanical factor of merit and also improves the damping factor. With moving elements of about the same weight for the two designs and with increased magnet strength, the control-spring torque is increased, thus providing quicker response of pointer.



A. Conventional instrument element design

B. New element design, General Electric type DW52

Figure 10

Conclusions

The development of a new magnet material for use in the d-c small panel electrical instrument has been described and its characteristics compared with other materials heretofore used for the same applications.

The application of this material has provided better over-all characteristics by virtue of increased gap flux density and has provided a basis for the design of a sturdy line of shallow electrical indicating instruments having sustained accuracy and increased range of sensitivity.

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Testing Aircraft Generators

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Synopsis: The modern fighting airplane requires a large amount of electric power for its successful operation. The aircraft generator provides a reliable source of power at the lowest possible weight. The development of these generators has required close co-ordination of design, testing, and interpretation of test results. The tests include raw material, parts, laboratory, life, mechanical, and flight tests. This paper describes tests which have been made and the interpretations which have led to improvements in d-c aircraft generators.

THE engine-mounted aircraft generator, Figure 1, operates under conditions which are more severe than in any other type of service. The generator must carry its load over an ambient temperature range of more than 125 degrees centigrade and from sea level to an altitude of 30,000 feet or more, as shown in Figure 2. Under normal operating conditions the engine vibration may subject the generator to an acceleration as great as 40 to 50 times the acceleration due to gravity. The generator also must operate successfully over a speed range as high as 2.5 to 1.

Weight must be low. Thus, each mechanical part is designed for maximum strength and minimum weight. The electric conductors are operated at current densities as high as 10,000 amperes per square inch. No excess material can be permitted in the magnetic circuit. It is essential that each part of this circuit be operated at the highest permissible flux density.

Purpose of Testing

The aircraft generator could not have been developed to its present state without close co-ordination of design, testing, and interpretation of test results. Raw materials and parts are tested and inspected to insure high quality before they are built into the machine. Each generator is given a commercial test to demonstrate its ability to carry the required load without mechanical or electrical failure. Laboratory tests are made to improve quality and to eliminate troubles which might develop later. Improvements are being made continuously, but these improvements must be tested thoroughly before they are adopted. An attempt is being made constantly to reduce weight, but any lightweight design must be tested first to prove that the generator is adequate, mechanically and electrically.

Paper 44-43, recommended by the AIEE committee on air transportation for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted November 13, 1943; made available for printing December 11, 1943.

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The author acknowledges the assistance of F. Cassel, R. Kimble, J. D. Miner, J. E. Mulheim, and other associates in assembling and preparing the material for this paper.

Quality-Control Tests

The testing of aircraft generators begins with the raw materials and parts. Insulation must be proved adequate before it is used in an aircraft generator. Poor-quality electrical sheet steel cannot be tolerated. High loss in the laminations requires extra engine power and reduces the range of the plane. High loss also requires extra cooling air and reduces the rating of a machine of given size. Certain types of poor-quality electrical sheet steel will age in only a few hours time if operated at high flux density and temperature. This material must be avoided in aircraft generators.

The initial quality of electrical sheet steel can be determined with a fair degree of accuracy by means of the standard tests for determining losses and magnetic properties. The aging quality can be determined only by the life tests described later in this paper.

Better mechanical strength is required in the teeth of aircraft-generator-armature punchings than in the standard rotating machine. The teeth must withstand the vibration encountered on the engine in addition to the stresses imposed by the centrifugal forces produced by the high operating speed.

The mechanical strength of any material can be determined easily by standard testing equipment. Special test equipment is required often to predict the performance in the finished generator. Some of this special test equipment is described later in this paper.

Commutators

The commutator of an aircraft generator is an especially important part. No generator can operate successfully without a commutator that is stable, both thermally and mechanically. The dimensions of the component parts must be controlled closely, and the commutator must be seasoned properly. Each commutator undergoes several cycles of heating and tightening during its manufacture, so that there will be no bar movement after it has been built into an armature.

Commutators also are given a potential test before assembly in the armature. They are tested at 1,200 volts (rms) to ground and at 110 volts (rms) between bars. These tests are made at standard frequency. After the armature has been assembled it is tested at 700 volts to ground and is then given a high-frequency test to detect short-circuited coils. The armature is tested between brush positions at 750 volts and approximately 375 kilocycles (Figure 3).

Table I. Corrosion Tests of Aircraft-Generator Parts

Salt-Spray Tests

Part	Material	Finish	Hours Before Rusting	Duration of Test	Per Cent Surface Rusted at End of Test
Bracket	Steel	Zinc (light)	48	240	90
Bracket	Steel	Zinc (heavy)		264	None
Brush band	Copper alloy	Lacquer		240	No corrosion
Brush band	Steel	Zinc (medium)	240	264	Less than 1
Brush springs	Steel	Cadmium	240	240	Less than 1

Tests of Completed Machines

Each sample generator is subjected to a series of tests to determine its performance in all respects. A complete test on a sample generator consists of these items:

1. High potential, cold.
2. Neutral setting.
3. Brush run-in.
4. No-load saturation.
5. Load saturation.
6. Commutation at various loads.
7. Maximum load.
8. Overspeed.
9. High potential, hot, after overspeed.
10. Field-current check after overspeed.
11. Temperature test.
12. Losses and efficiency.
13. Ventilation.

Commutation is of great importance in d-c aircraft generators. Excessive

Figure 1. 28.5-volt 200-ampere type *P*-1 aircraft generator

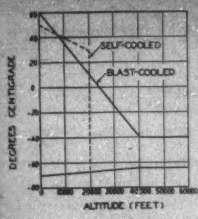


Figure 2. Temperature and altitude range of aircraft-generator operation

sparking causes short brush and commutator life and increased losses due to the circulating currents which are produced. Testing the preliminary sample permits the engineer to make the necessary adjustments and changes to improve commutation. The electrical performance of aircraft generators cannot be calculated nor predicted so accurately as that of large power machines. Changes after test are often necessary, but the engineer is guided by the tests in making changes. Commutation is improved frequently by a change in one or more of the following items:

1. Interpole ampere turns.
2. Interpole air gap.
3. Length of interpole.
4. Amount of compensation.
5. Neutral setting.
6. Grade of brush.

Production Tests

It is unnecessary to make complete tests on each machine that is built in daily production. Certain standard commercial tests will determine whether or not a generator will meet the expected performance. Each production generator should be given the following tests:

1. High potential, cold (500 volts rms).
2. Neutral setting.
3. Brush run-in.
4. Field current at minimum speed, maximum load, and rated voltage.
5. Overspeed test.
6. High potential, hot (500 volts rms).
7. Field-current check after overspeed test.

One production generator in approximately 20 should be given a full-load temperature test. This test should be made under standardized conditions. By comparison with previous tests any large change in losses can be detected At regular intervals a complete test should be made, including separation of losses to provide a close check on quality of material.

Life Tests

Aircraft generators are different from standard machines, because the fullest use is made of every mechanical and electrical part. They cannot be designed for infinite life, because the weight would then become excessive. They are so designed that each part is worked to the utmost, and no part can have an excessive factor of safety. It is essential that some method be provided for determining any inherent weakness which might be present in the machine. Thus, life tests are made frequently on aircraft generators. The generator is connected to a driving motor of sufficient capacity and then loaded at its maximum rated load. The generator may be overloaded to determine the overload capacity.

Aircraft generators may fail either for mechanical or electrical reasons. The purpose of the life test is to discover the weakest part of the generator, so that the weakness may be corrected. For best results the life test must be run over a long period of time or until some part of the machine fails.

The commutation of the generator and the brush life can be studied best by means of the life test. Since the test is continued over a long period of time, the brush life can be determined accurately, and any change in the commutation can be observed. Thus, in conjunction with altitude tests, it is possible to select experimentally the grade of brush which will give the best performance over the life of the generator. The laboratory life test is conducted at sea level and cannot predict the performance at altitude. The brush life test must be co-ordinated with the altitude and flight tests described later.

The quality of insulation in a generator at the time of its manufacture is determined by the dielectric or high-potential test which is made during routine factory tests. These tests are no assurance that the insulation will not deteriorate and fail before the machine has operated for its expected life. The life test reproduces operating conditions and temperatures which are found in actual service. The use of the high-potential test at frequent intervals during the life test will demonstrate any weakness in the insulation.

The losses of poor-quality electric sheet steel will increase during the life of the generator. The high operating temperature of aircraft generators has an accelerating effect upon the normal increase in losses, caused by aging. Measurement of iron loss before and after the tests will show whether or not the iron has maintained its initial qualities.

Figure 3 (left). High-frequency test apparatus for armatures of aircraft generators

Figure 4 (right). Altitude chamber for testing aircraft generators

The electrical parts of an aircraft generator are designed to withstand a higher continuous operating temperature than the bearings. If the flow of air is obstructed, so that the bearings are not adequately cooled, failure will result. The life test, continued over a long period of time, will show up any defect in bearing design, manufacture, application, or ventilation.

Insulation

Except for commutation and voltage regulation, the ability of an aircraft generator to carry load depends on the temperature of the windings. Class-*A* insulation will withstand a temperature of 105 degrees centigrade for a period of several years. Class-*B* insulation will withstand a temperature of 125 degrees centigrade for a similar period. The two classes of insulation will withstand higher temperatures for shorter periods of time. Thus, in the life of an aircraft generator, class-*A* insulation can be operated at 130 degrees centigrade, and class-*B* insulation can be operated at 150 degrees centigrade without affecting the normal life of the machine.

The temperature of the windings of an aircraft generator should not exceed that for which they are designed. High temperature can be expected in the armature, so that class-*B* insulation should be used where needed. The highest temperature occurs between the two coil sides in a slot. Glass-insulated wire has been found to be best for armature conductors. A thin fish-paper cell often is suitable for the slot insulation, because the temperature is several degrees cooler than it is between the conductors.

No generator can operate for its maximum useful life without an adequate factor of safety in the insulation. The insulation must withstand the temperature to which it is subjected as well as maintain the required dielectric strength. The life test is the only successful way of determining whether or not the insulation will stand up. If the generator will withstand the initial test voltage after operating for a time equal to the expected life of the generator, the insulation can be considered adequate. Similar tests resulted in the adoption of the glass-covered wire mentioned in the preceding paragraph.

Ventilation

Most aircraft generators are forced-ventilated with the air passing axially through the generator. The quantity of air which passes through a 200-ampere 28.5-volt generator is approximately 75 cubic feet per minute at six inches of water, total pressure. Since the quantity is small, the air must be used effectively. All air passages should be designed so that the velocity is high. No passage should be permitted to short circuit any path where the air is needed for most effective cooling. Large openings through the rotor may prevent effective cooling of the stator.

Measurement of air pressure must be made at the generator. If measurement is made at a distance from the generator, the pressure drop between the point of measurement and the generator may be enough to affect seriously the accuracy of the test.

When an aircraft generator is installed on the engine, no avoidable obstruction should be permitted in the air passage leading to the generator. Back pressure in the engine nacelle reduces the amount of cooling air which the generator receives. Most aircraft generators are designed to deliver their rated output when cooling air is supplied at ten inches of water, total pressure. Usually not more than six inches is available at the generator. This reduces the maximum load which the generator can carry safely.

Figure 5. Rotor of aircraft-generator brush tester

Figure 6. Aircraft-generator brush tester showing brushes in place

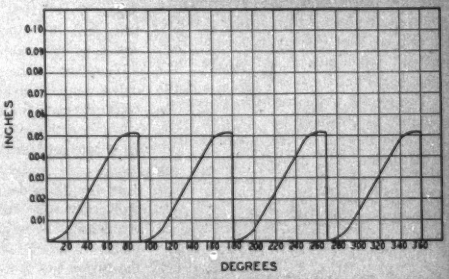


Figure 7. Curve showing contour of the rotor of brush tester

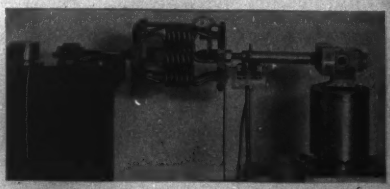


Figure 8. Fatigue-test arrangement for aircraft-generator brackets

Engine Tests

The life test gives valuable data concerning the performance of an aircraft generator but does not duplicate the actual operating conditions encountered on a plane. The engine test often is used to reproduce more closely these operating conditions. The generator is mounted directly on an engine which drives a propeller. Thus, the generator

must withstand approximately the same vibration that is encountered on an airplane.

An engine test is an excellent means of determining the ability of the generator to resist mechanical shocks and vibration. In addition, this test is a means of testing the performance of the gear unit through which the generator is driven.

Flight Test

No test has been found yet which will duplicate exactly the operating conditions that are found on an airplane. The final data as to how a generator performs must come from actual flight. These data may be obtained either from a special airplane used only for experimental purposes or from other airplanes where records are kept of flight conditions. It is difficult sometimes to obtain the complete history of the flight test.

The special test airplane has been invaluable in obtaining test data on commutation and the performance of brushes at altitude. The normal flight is one hour in ascent, three hours at altitude, and one hour in descent. The load is controlled during flight, so that operating conditions are known accurately.

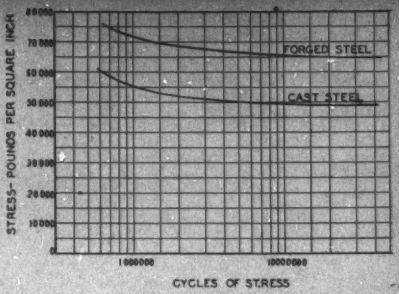
Altitude Chamber Tests

By means of the altitude chamber it has been possible to reproduce closely the conditions which are encountered when the airplane flies at an altitude of 30,000 feet or higher. A cooling system is provided, so that the low temperatures of altitude flying can be obtained. The low pressure within the chamber is maintained by means of a vacuum pump. A drive shaft extends through the wall of the chamber. Terminals are provided for electric connections. Any electrical condition which the generator encounters on an airplane can be reproduced closely in the altitude chamber. A small altitude chamber is shown in Figure 4.

Brush Tests (Mechanical)

The brushes of aircraft generators are subjected to severe mechanical operating conditions. Brushes have failed because of breakage, loose rivets, broken shunts, or frayed insulating sleeving. A vibration tester has been devised for testing brushes mechanically. The tester consists of two brush-holder assemblies mounted in a generator frame together with two commutators which have been machined, so that each brush drops approximately $^{1}/_{64}$ inch four times in one revolution. The tester shown in Figures 5 and 6 will test 16 brushes at one time. The contour of the rotor is shown in Figure 7. This is an extremely severe test, probably more than 100 times as severe as the condition encountered on an airplane. The vibration tester will detect any mechanical weakness in the brush in only a few hours operating time.

Figure 9. Fatigue tests of aircraft-generator brackets



Brackets and Bolts

In the early days of 200-ampere aircraft generators much trouble was encountered due to broken brackets and bolts. A die-cast bracket was used on the engine end of the generator, and this was unable to withstand the vibration and shocks encountered. Trouble was encountered also with breakage of the screws which are used to attach the bracket to the generator yoke. Extensive fatigue tests were made to determine the source of trouble and how the bracket design could be improved to eliminate the trouble. The test setup is shown in Figure 8. The curves shown in Figure 9 were obtained from these tests.

Corrosion

Aircraft generators are required to operate in any kind of climate. An open piece of electrical apparatus cannot be made entirely corrosion-proof, but the parts should be made so that they will resist the weather conditions commonly encountered. To establish their ability to resist corrosion, a series of tests was made on aircraft-generator parts. These results are shown in Table I.

As a further check, outdoor corrosion tests were made on two *P*-1 generators completely assembled. One generator was placed under a shelter, open at the sides. The other generator was exposed completely with no protection. The generators were mounted horizontally with the air connection downward. They were taken from the assembly line and were given no additional treatment. The generators were exposed for four weeks during the past summer. Rain fell several times during the test.

At the end of four weeks the only evidence of corrosion was a slight amount of rust on the steel parts inside the generator and on the spline. The insulation resistance varied from day to day, but at the end of the test it was as high as it was at the beginning. There was no apparent difference in the appearance of the two generators at the end of the test, although one had been under a cover, and the other had been exposed entirely. The paint was in good condition at the end of this test.

Conclusions

The test program for aircraft generators has required much testing of generator parts as well as of complete machines. The object of all of these tests has been to build the most reliable generator with the lowest possible weight. The test program has been responsible for the correction of the troubles which have developed in the field and for the elimination of potential sources of trouble. The test program is not complete and never will be complete so long as aircraft generators are built. The life test has been responsible for a great amount of improvement in aircraft generators. By means of these tests in which the generator carries a definite load, the life of insulation has been studied. It has been possible to apply the insulation, so that each electrical part is insulated adequately. Class-*A* material has been used where it is adequate for the operating temperatures encountered in aircraft generators. Class-*B* insulation has been used where required because of higher temperatures, as in the armature conductors. The insulating material has been chosen also, so that the generator will withstand the potential tests with an adequate margin.

Potential Breakdown of Small Gaps Under Simulated High-Altitude Conditions

M. J. DeLERNO
ASSOCIATE AIEE

CONCURRENT with the present development program of a 400-cycle 208-volt power supply for aircraft, it was deemed advisable to study the effect of high altitudes on the breakdown potential between various conductors at different voltage levels.

Aircraft electrical equipment will be subjected to severe and unusual conditions which will affect materially high potential specifications. Some of the most severe conditions are:

(*a*). Airplanes may be parked on the ground for several weeks without seeing use. In equatorial regions the moisture content of the air may be very high and may even reach 100 per cent. Operation of equipment under such humid conditions may affect breakdown potential values.

(*b*). Airplanes will be flying part of the time at high altitudes (40,000 feet) and part of the time at lower altitudes. At the high altitudes all equipment not heated or located in a heated section of the plane will get very cold. When the plane descends to lower altitudes, the humidity and temperature will be higher, and moisture will probably condense on the cold equipment, first as frost and later as moisture.

(*c*). In many cases airplanes are forced to fly from dusty fields or through dust storms. Any exposed surfaces may be contaminated by dust.

Paper 44-29, recommended by the AIEE committee on air transportation for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted November 3, 1943; made available for printing December 1, 1943.

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Scope of Investigation

The breakdown potential is that potential which causes complete breakdown or flashover between the electrodes. It is defined as the potential which will produce a luminous discharge between the electrodes. This discharge may clear itself immediately or may be followed by an arc, depending upon the power capacity and the impedance of the electric circuit. The chief characteristic of an arc discharge is the low voltage drop between the electrodes.

In order to simulate true high-altitude conditions, it is necessary to reduce both the pressure and temperature of the air which surrounds the test specimen to the same degree which exists at any specified altitude. However, several devices in airplanes are located near pieces of equipment which operate at high temperatures and which consequently heat the air in the vicinity. These devices therefore may be surrounded by an atmosphere which is at the same pressure but at higher temperature than the air which normally exists at that altitude. It will be shown from theoretical considerations that, for any given gas pressure and electrode spacing encountered on aircraft equipment, the breakdown potential usually decreases with an increase in temperature. Since higher temperatures decrease the breakdown potentials, it was thought best to perform all tests at reduced pressures corresponding to any given altitude but to leave the air temperature fixed at its sea-level value.

In production testing of 400-cycle equipment to determine dielectric defects, a source of 400-cycle power is not usually available, and it is therefore necessary to use 60-cycle supply. A comparison between breakdown at 400 cycles and 60 cycles under similar conditions was undertaken to establish a relationship between them. This was also desirable since breakdown data which had been taken previously with 60-cycle supply could be converted to equivalent 400-cycle data.

The two types of breakdown affected by high altitudes are air-gap breakdown and surface or creepage breakdown. Designers of low-voltage electrical control equipment sometimes use air-gap breakdown values between spheres and creepage breakdown values in a uniform

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Improvements in brush life have depended mostly on generator life tests. By co-ordinating the life tests at sea level with the data obtained from the altitude chamber and flight tests, the best possible brush has been obtained. A brush has been developed which has satisfactory life both at sea level and at altitude. The subject of brush development is too broad to be more than mentioned in this paper.

The tests which have been made in the vibration tester shown in Figures 5 and 6 have enabled the mechanical development of brushes to keep ahead of the requirements in the airplane. The rarity of mechanical brush failure can be attributed to improvements which have been made as a result of tests made in the vibration tester.

The altitude chamber has not been used long enough to determine its fullest possibilities for testing generators. The tests which have been made already show that altitude conditions can be reproduced very closely. The chamber tests in conjunction with the life test at sea level will facilitate the improvement of brushes and commutation.

The mechanical forces encountered in engine tests are nearly the same as those encountered in flight. These tests have been of great value in determining the adequacy of brackets, bearings, connectors, leads, and terminals.

The flight test permits a close check to be made on the test data obtained in the altitude chamber. Brush improvements which have been made as a result of altitude chamber tests must be given the final test in flight. Flight tests cannot be made so easily nor so often as tests in the altitude chamber but are of great value, because the generator encounters exactly the same conditions that are found in actual service. In addition to brush tests, flight tests like engine tests have served to test the ability of brackets, bearings, leads, and connectors to stand up in service.

Laboratory tests of generator parts have enabled the engineers to improve these parts; thereby many sources of trouble have been eliminated. No untried part can be used on an aircraft generator. Laboratory tests must be relied on for a preliminary check of all improvements before they are subjected to engine or flight tests.

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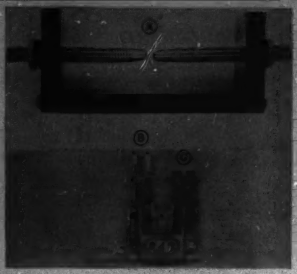

Figure 1. Air-gap breakdown specimens

A. 1/4-inch-diameter brass hemispheres
B. Parallel straight silver-plated phosphor-bronze strips, 0.010 inch thick. Air gap, 0.187 inch
C. Parallel L-shaped silver-plated phosphor-bronze strips, 0.031 inch thick. Air gap, 0.117 inch

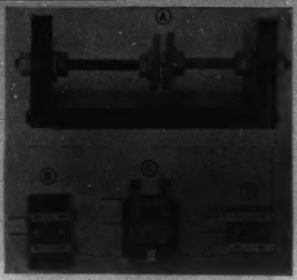

Figure 2. Creepage breakdown specimens

A. Uniform field specimen
B. Textolite, 0.12-inch spacing
C. Textolite, 0.035-inch spacing
D. Hot-molded compound, 0.13-inch spacing

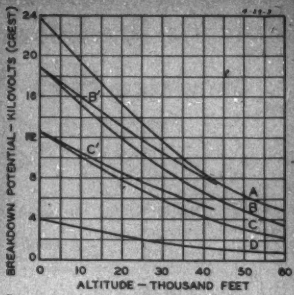

Figure 3. Hemisphere-gap breakdown characteristics

1/4-inch-diameter brass electrodes

A. 1/2-inch gap. Air temperature 72 degrees Fahrenheit
B. 1/4-inch gap. Air temperature 72 degrees Fahrenheit
B'. 1/4-inch gap. Air temperature corresponds to various altitudes (calculated)
C. 1/8-inch gap. Air temperature 72 degrees Fahrenheit
C'. 1/8-inch gap. Air temperature corresponds to various altitudes (calculated)
D. 1/32-inch gap. Air temperature 72 degrees Fahrenheit

electrostatic field as a preliminary basis for determining minimum clearances on new designs (when not specified in an AIEE or similar standard). At best, conclusions obtained in this manner can approximate only roughly actual conditions on aircraft equipment, for the potential field produced between various aircraft parts is quite different from that which exists between spheres or between parallel plates (uniform field). Therefore, air-gap and creepage breakdown potentials were taken between various parts of aircraft relays and contactors in addition to tests taken on hemisphere gaps and uniform-field specimens.

In order to reproduce conditions which may exist in part *b* of the introduction, several aircraft relay parts were cooled to 0 degrees Fahrenheit and were then placed in a chamber which was maintained at about 85 per cent humidity. Voltage was applied between current-carrying parts of the specimen shortly after introduction into the chamber.

Test Equipment

The mechanical equipment used in performing the tests consisted of a bell jar in which the tests were conducted, a rotary vacuum pump for evacuating the bell jar, a thermometer, a humidity meter, a container of calcium chloride for drying the air, and a jar of water for raising the humidity of the air. Electrical connections to the test specimen were made through studs at the top of the bell jar.

The electric circuit consisted of a step-up transformer supplied by either a 60-cycle or a 400-cycle alternator. A series resistor was inserted between the alternator and transformer to limit the discharge current after breakdown occurred. A foot switch was also located in the transformer primary circuit to interrupt the circuit when breakdown occurred. In this way it was possible to use the same specimen for a large number of tests before carbonization of the specimen occurred. The breakdown potential was measured with a step-down potential transformer and a voltmeter. The wave form of the voltage across the power transformer was not a true sine wave because the alternator voltage did not have a true sinusoidal wave form. Therefore the voltages measured with the potential transformer were calibrated with voltages measured across the test specimen with a crest reading voltmeter.

The test specimens are shown for air-gap breakdown in Figure 1 and for creepage breakdown in Figure 2. All specimens, except hemispheres and the uniform-field specimens, were obtained from standard aircraft relay parts and will simulate actual conditions which exist on aircraft.

Summary of Data

Table I shows the per cent difference between the average breakdown potential (average of ten readings) for 60 cycles with that for 400 cycles at 72 degrees Fahrenheit for reduced pressures corresponding to various altitudes. Although there are a few cases in the table in which the difference exceeds ten per cent, it should be pointed out that variations in

Table I. Comparison Between Breakdown Potentials at 60 and at 400 Cycles

Specimen	Specimen Number	Electrode Spacing (Inches)	Per Cent Difference $\frac{V(60) - V(400)}{V(50)} \times 100$ Altitude (Feet)* 0	15,100	30,300	45,200
Air-Gap Breakdown						
Parallel straight relay strips, Figure 1B	1	0.187	2.9	−3.8	3.8	−3.7
	2	0.187	0.4			0.8
Parallel L-shaped relay strips, Figure 1C	1	0.117	−2.0	7.9	4.8	7.7
	2	0.117	0.6			−5.0
Creepage Breakdown (Nonuniform Field)						
Textolite, Figure 2B	1	0.125	0.3	8.0	0	−13.0
	2	0.125	−0.3	0.9	− 0.6	−19.1
	3	0.125	0.3			−24.6
	4	0.125	1.8			−13.3
Textolite, Figure 2C	1	0.035	−8.2	−8.7	−10.4	1.4
	2	0.035	−3.0	−2.3	− 1.0	5.1
	3	0.035	1.9			− 2.8
	4	0.035	5.4			2.7

* Corresponds to pressures existing at the specified altitude, but not to temperatures. Temperature held at 72 degrees Fahrenheit.

Table II. Effect of High Humidity on the Creepage Breakdown Potential of Precooled Specimens

Specimen	Specimen Number	Electrode Spacing (Inches)	Number of Tests	Per Cent Difference: Min (A)* − Min (B)** / Min (A) × 100, Altitude (Feet)† 0	Per Cent Difference: Min (A)* − Min (B)** / Min (A) × 100, Altitude (Feet)† 45,200	Per Cent Difference: Avg (A)* − Avg (B)** / Avg (A) × 100, Altitude (Feet)† 0	Per Cent Difference: Avg (A)* − Avg (B)** / Avg (A) × 100, Altitude (Feet)† 45,200
Textolite, Figure 2B	1	0.125	3	25.3	28.6	16.0	2.0
	2	0.125	2	32.1	18.8	20.2	15.5
	3	0.125	1	22.0		− 1.4	
	4	0.125	1	21.8		10.2	

* (A) Breakdown potential of a dry specimen.

** (B) Breakdown potential of a specimen subjected to special moisture conditions.

† Corresponds to pressures existing at the specified altitude, but not to temperatures. Temperature held at 72 degrees Fahrenheit.

the average high potential breakdown at 60 cycles for different specimens having the same dimensions and constructed of the same materials have exceeded 25 per cent. Since 64 per cent of the differences are less than ±five per cent and 86 per cent less than ±ten per cent, it seems justifiable to conclude that there is no appreciable difference between 60- and 400-cycle high-potential breakdown values for the range of electrode spacings used.

Similar conclusions may be drawn on the effect of humidity on high-potential air-gap and creepage breakdown values. A comparison between tests performed with 20 per cent relative humidity and with 85 per cent relative humidity at 72 degrees Fahrenheit for reduced pressures corresponding to various altitudes showed that 50 per cent of the differences between the average breakdown values (average of ten readings) at 20 per cent humidity and 85 per cent humidity, divided by the average breakdown values at 20 per cent humidity are less than ±five per cent, and 80 per cent are less than ±ten per cent. These results indicate that humidity has inappreciable effect on air-gap breakdown potential characteristics and on creepage breakdown potential characteristics for the materials tested.

Tests which were conducted on specimens which had been cooled to 0 degrees Fahrenheit and then placed in a high humidity atmosphere (85 per cent) at 72 degrees Fahrenheit showed that moisture condensed on the surfaces of the specimens. The moisture lowered the initial creepage breakdown potential of a specimen, but successive breakdowns dried the surface sufficiently to raise the breakdown potential to its average dry value. It should be pointed out that if the electric circuit is such that an arc can follow the initial spark, then the surface of the insulation is usually carbonized by the arc to such an extent that a permanent short circuit is created between the electrodes. Since repeated flashovers raise the breakdown potential nearly to the dry breakdown potential, then the per cent difference between the minimum breakdown potential of a dry specimen and the minimum breakdown potential of the same specimen when treated as already stated is more important than the per cent difference between the average values of the dry specimen and the treated specimen. Table II shows the per cent difference for both the minimum and average values. Ten readings were obtained for each test, from which the minimum and average values were obtained. Sometimes more than one test was performed on a specimen, and, when such was the case, the minimum and average values were obtained from the total number of readings. It was found from experimental tests that the initial breakdown potential of ceramic specimens when subjected to this special moisture condition could be raised about 25 per cent by treating the ceramic with the vapors of silicon methyl chloride (a silicone derivative). This treatment produces a ceramic surface which is water repellant and which has a very high electrical surface resistivity under dew-point conditions.

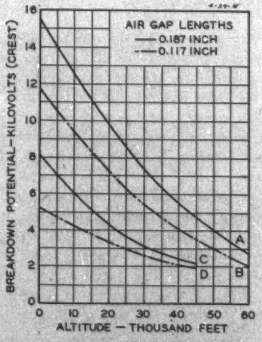

Figure 4. Comparison of air-gap breakdown between parallel strips with air-gap breakdown between hemispheres

A-B. 1/4-inch-diameter brass hemispheres. Air temperature 72 degrees Fahrenheit

C. Parallel straight silver-plated phosphor-bronze strips, 0.010 inch thick. Air temperature 72 degrees Fahrenheit

D. Parallel L-shaped silver-plated phosphor-bronze strips, 0.031 inch thick. Air temperature 72 degrees Fahrenheit

(See Figure 1 for picture of specimens)

Breakdown potential values under various conditions are shown in Figures 3, 4, and 5. Figure 3 shows the hemisphere-gap breakdown characteristics for different electrode spacings. It also shows the effect of reduced temperatures on the breakdown characteristics based on theoretical analysis. Figure 4 compares the air-gap breakdown characteristics between hemispheres with the air-gap breakdown characteristics between various aircraft relay parts. Figure 5 makes a similar comparison between creepage breakdown in a uniform and nonuniform electrostatic field.

From curves similar to Figures 3, 4, and 5, a table showing the ratio of breakdown potential at sea level to a pressure corresponding to 45,000 feet elevation for an air temperature of 72 degrees Fahrenheit for both air-gap and creepage breakdown has been compiled. Table III shows this ratio. This ratio is important in determining equivalent sea-level high-potential voltage values to correspond to altitude high-potential values. If the AIEE specification requiring electrical equipment to withstand a high-potential

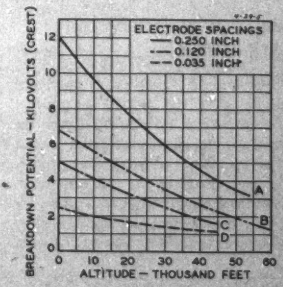

Figure 5. Comparison between creepage breakdown in a uniform electrostatic field and creepage breakdown in a nonuniform electrostatic field

A-B. Breakdown across Textolite surface located in a uniform field. Air temperature 72 degrees Fahrenheit

C-D. Breakdown across Textolite surface located in a nonuniform field. Air temperature 72 degrees Fahrenheit

(See Figure 2 for picture of specimens)

Table III. Ratio of Breakdown Potential at Sea Level to 45,000 Feet*

	Ratio V(0) to V(45,000)
Air-Gap Breakdown	
Hemisphere gap: 1/32-inch spacing	3.5
Hemisphere gap: 1/8-inch spacing	3.4
Hemisphere gap: 1/4-inch spacing	3.3
Hemisphere gap: 1/2-inch spacing	3.3
Parallel straight strips—0.187-inch gap	3.7
Parallel L-shaped strips—0.117-inch gap	2.7
Creepage Breakdown	
Uniform field	
Textolite: 1/8-inch thick (arc with grain)	3.4
Textolite: 1/8-inch thick (arc with grain)	3.0
Textolite: 1/8-inch thick (arc across grain)	3.0
Textolite: 1/8-inch thick (arc across grain)	2.8
Cold-molded asbestos compound: 1/8-inch thick	2.8
Cold-molded asbestos compound: 1/4-inch thick	3.0
Nonuniform field	
Hot-molded compound (Bakelite material 1122) 0.13-inch spacing	3.5
Textolite: 0.125-inch spacing	3.1
Textolite: 0.035-inch spacing	2.1

* Corresponds to pressures existing at the specified altitude, but not to temperature. Temperature held at 72 degrees Fahrenheit.

voltage of twice rated voltage plus 1,000 volts is to apply at 45,000 feet, then the same equipment will have to withstand from 2.7 to 3.7 times as high a voltage at sea level. On 208-volt circuits, the equipment would have to withstand 1,416 volts at 45,000 feet and from 3,820 to 5,240 volts at sea level. Such a specification is rather severe under such conditions, and it would seem that a more satisfactory specification would be to require an equivalent sea-level voltage of 2.7 to 3.7 times twice rated voltage plus an additional 1,000 volts. On 208-volt equipment, the equivalent sea-level voltage would then be from 2,122 to 2,540 volts.

Comparison With Theoretical Performance

Experimental tests made by Peek[1] indicate that the breakdown voltage between spheres is independent of the frequency, provided corona is not present before breakdown to provide a considerable space-charge effect. He also determined from experimental tests[2] that, for spheres, corona does not appear before breakdown until the spacing between the spheres equals eight times the radius of the sphere. The maximum spacing-radius ratio for the hemispheres was four (1/2-inch gap, 1/8-inch radius). The theory, therefore, seems to check the data that breakdown characteristics for hemisphere gaps are the same at 60 and 400 cycles.

The effect of humidity on air-gap breakdown for sphere gaps is inappreciable if the surfaces remain dry,[3] while the effect of humidity on needle gaps is to require a higher voltage to cause breakdown when the humidity is high than when it is low.[4] These two conditions correspond somewhat to the hemisphere gap and the air gap between various parts of relays, respectively. However, no humidity effect was observed on gaps between various relay parts.

In order to check the effect of reduced temperatures on the breakdown characteristics of air gaps, use was made of the principle of similitude.[4] This principle, which was developed by Townsend, states that, for geometrically similar systems, the breakdown potential is a function of only the product of gas density and one of the linear dimensions of the system, provided no space-charge effect is present before breakdown. Since the gas density is directly proportional to the gas pressure and inversely proportional to the gas temperature, then an equation expressing these statements will be

$$E = f(\rho \times d) = f_1\left(\frac{P}{T} \times d\right)$$

where E is the breakdown potential, ρ the gas density, T the absolute gas temperature, P the absolute gas pressure, and d the linear dimension of the system.

To convert breakdown characteristics at room temperatures to temperatures corresponding to various altitudes, the value of P/T must remain constant if E and d are held fixed. By reading the value of E corresponding to some pressure and 72 degrees Fahrenheit from the experimental curves of Figures 3 and 4, and calculating the P/T ratio, a new value of P and T corresponding to some altitude can be picked which will give the same P/T ratio. The value of E will then apply to the new temperature and pressure conditions which are the true conditions existing at that altitude. Figure 3 shows curves calculated in this manner.

Conclusions

The following conclusions may be drawn from the data presented:

1. Air-gap and creepage breakdown characteristics are substantially the same for 60- and 400-cycle supply for short gaps.

2. The effect of a very humid atmosphere on air-gap and creepage breakdown potentials is inappreciable, provided there is no moisture condensation on the electrodes or the dielectric.

3. About 25 per cent reduction in the initial creepage breakdown potential can be expected if there is appreciable moisture condensation on the surface of the dielectric. Succeeding breakdown values will approach gradually the flashover value for the dry dielectric, provided the surface does not become carbonized.

4. Treating ceramic parts with a silicone vapor will raise the initial creepage breakdown about 25 per cent if there is considerable moisture condensation on the surface of the ceramic.

5. Breakdown characteristics obtained on aircraft relay and contactor parts may differ as much as 100 per cent from characteristics obtained from sphere-gap observations for air-gap breakdown or from uniform-field breakdown observations for creepage breakdown.

6. The ratio of air-gap or creepage breakdown potential at sea level to pressures corresponding to 45,000 feet varies from 2.7 to 3.7, depending upon the electrode shape and spacing for air-gap breakdown, and on the dielectric material and the electrostatic field distribution betweeen the electrodes for creepage breakdown.

References

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3. Reference 1, page 119.

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5. Conduction of Electricity in Gases (book) Joseph Slepian. 1933. Pages 119–24.

High-Voltage Oil Circuit Breakers for Rapid Reclosing Duty

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Synopsis: Experience has shown that high-speed reclosing of circuit breakers on high-voltage transmission lines is of considerable value in maintaining system stability and continuity of service. This paper describes a new line of outdoor oil circuit breakers and the special design features which make them suitable for 20- and 35-cycle reclosing duty at voltages as high as 230 kv. Data are included showing high-power-laboratory short-circuit tests on these duty cycles at 138 kv and 230 kv at currents corresponding to three-phase duty of more than 2,500,000 kva.

THE present emergency demands the highest possible reliability in the electrical systems which are supplying unprecedented loads to industrial centers. In many locations the use of high-speed reclosing of high-voltage circuit breakers has proved to be of great value in maintaining continuity of service. System-stability requirements have brought about the development of high-speed circuit breakers in the voltage range from 115 kv to 287 kv with an interrupting time of five or even three cycles. In recent years, a few of these high-speed breakers have been available with provision for high-speed reclosing. This paper describes the design and performance of a line of high-voltage circuit breakers particularly designed to meet these severe operating requirements.

Because of the arc-interrupting effectiveness and low arc energy of multiflow deion grid contacts described in a paper before the Institute a year ago,[1] it is possible for the physical size of these high-voltage reclosing circuit breakers to be smaller than the older standard breakers. Simplification of the operating mechanism is made possible by utilizing the recently developed compressed-air type of mechanism for operating high-voltage oil circuit breakers.[2] Short-circuit tests made in the high-power laboratory have demonstrated the ability of these new circuit breakers to interrupt on either a 35-cycle or a 20-cycle reclosing duty cycle short-circuit powers as high as 2,500,000 kva.

The new interrupter for these oil circuit breakers, called the multiflow deion grid, is smaller in size than earlier forms of contacts. From the nature of its operation the arcs are kept under control at all times, and the evolution of gas is so reduced that very little space is needed for insulation around the grid. The live parts are compactly enclosed within well-rounded metallic shields so that the voltage gradient through the oil is low enough to allow the most effective use of well-co-ordinated striking and creepage distances. For still higher interrupting capacities which are necessary to meet present-day requirements, such as 3,500,000 kva, interrupting units built with a greater degree of ruggedness perform entirely satisfactorily.

The bushing-type current transformers are built to modern American Standards Association and National Electrical Manufacturers Association standards. The standard design of one current transformer per bushing fulfills usual requirements, although ample space can be made available to provide for two transformers per bushing where required, either multiratio on the Hipersil core for relaying purposes or single ratio on the Hipernik core for high-accuracy metering service. The small bushing diameter is also an advantage here, as it permits plenty of space for the transformers without making necessary the use of protruding casings to mar the otherwise smooth-walled tank.

The new line of breakers presented an opportunity to make a new design of pole-unit levers, better adapted to high-speed operation. The general features required for straight line motion which have been used for so many years have been retained, but, with the more effective interrupters, it is now possible to reduce the length of travel and yet keep ample toggle effect at the closed position of the contacts. Fabricated steel levers and links are used throughout as shown in Figure 1. The load characteristic (Figure 2) gives the various increments of load for the entire closing stroke, plotted against mechanism pull-rod travel. In other words, each static load inside the three tanks, such as the dead weight of the contacts and levers, and the contact-spring load is multiplied by the pull ratio, to convert it into equivalent load at the operating mechanism. Since the accelerating spring for the mechanism illustrated is outside the tank, it is added without being modified by the pull ratio. A summation of these increments shows a net load increasing from slightly over 1,000 pounds at the open position, to a little over 3,000 pounds at the closed position, all of which is well within the ability of either the conventional solenoid or pneumatic mecha-

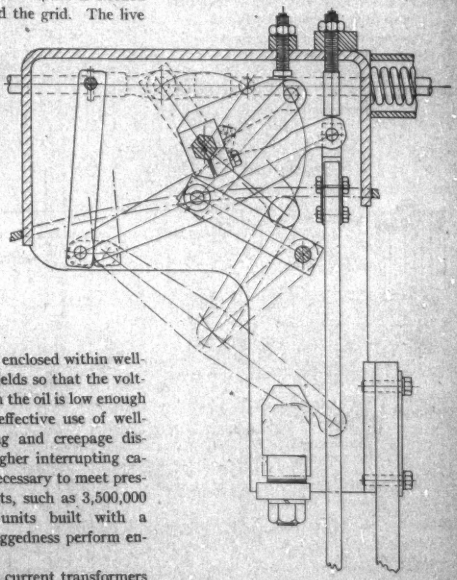

Figure 1. Pole-unit lever system for 138-kv breaker, showing relation of toggles, stops, dashpot, and accelerating spring

Paper 44-37, recommended by the AIEE committee on protective devices for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted November 26, 1943; made available for printing December 10, 1943.

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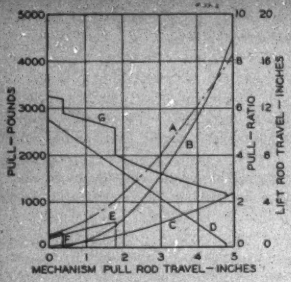


Figure 2. Load curve for three-pole 138-kv breaker

A. Pull ratio of levers showing greatest mechanical advantage at closed position of stroke
B. Relation of lift-rod travel to operating-mechanism travel
C. Equivalent weight of pole-unit levers, contacts, and so forth, expressed as equivalent mass at the operating mechanism
D. Accelerating spring load in pounds
E. Intermediate contact load
F. Main contact load
G. Total load on operating mechanism. Summation of *C-D-E-F*

nism. In this class of breaker the added load due to forces encountered in closing against fault currents is negligible and hence can be neglected.

Compressed-Air Operating Mechanism

A schematic view of the compressed-air operating mechanism, suitable for high-speed reclosing, is illustrated in Figure 3. The operating system is connected at all times to the main-breaker operating rod, only one lever being required for latching purposes. During the closing operation, air is admitted to the top of the cylinder, forcing the piston down to the closed position where it is held by the latch. Energizing the trip coil also operates a large "dump valve" arranged so that any air left in the cylinder on the top side, as for example on immediate tripout after closing, will be exhausted sufficiently rapidly to give full opening speed. The acceleration on opening is provided entirely by springs so that even in the event of failure of the compressed-air system, the breaker could perform its protective function of clearing the circuit. To obtain rapid reclosing it is necessary to time the opening of the valve admitting air to the cylinder such that the breaker will be brought to rest before the normal full-open position but with ample margin for interrupting the arc, and returned to the closed position within the required time. A record of a timing test showing an open–close–open operation is illustrated in Figure 4. It is to be noted that the velocity of contact opening is essentially the same on the second tripping as on the first, illustrating the effectiveness of the dump valve in giving pneumatically trip-free operation as an alternative to mechanically trip-free operation.

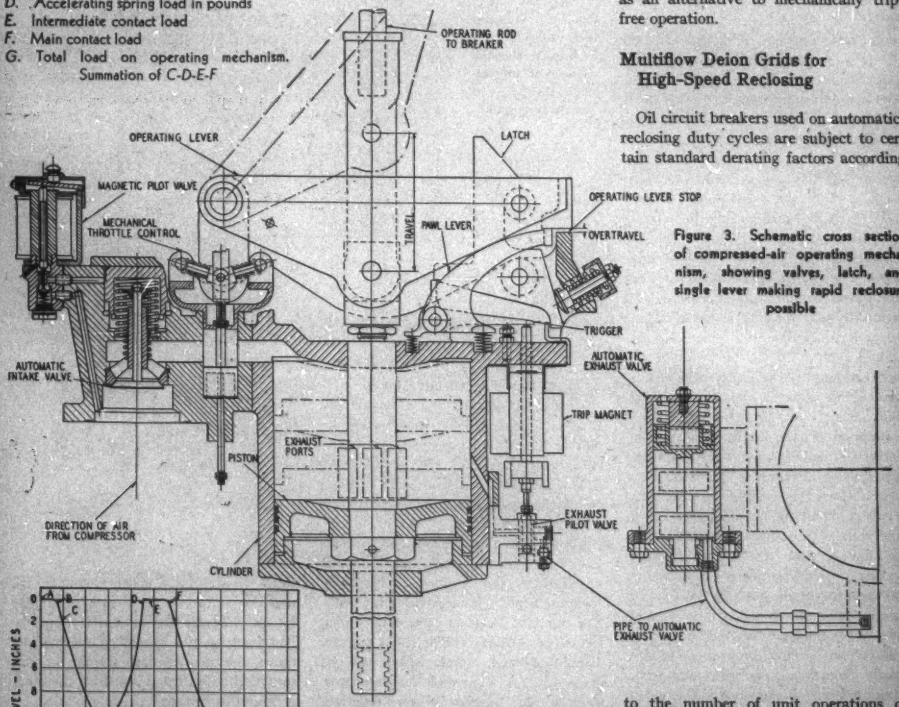


Figure 3. Schematic cross section of compressed-air operating mechanism, showing valves, latch, and single lever making rapid reclosure possible

Multiflow Deion Grids for High-Speed Reclosing

Oil circuit breakers used on automatic-reclosing duty cycles are subject to certain standard derating factors according to the number of unit operations or groups of unit operations. For instance, a circuit breaker having an interrupting capacity between 5,000 and 10,000 amperes on the standard two-CO–15-second duty cycle (two-unit operation) will have a rating of only 85 per cent when the two-unit operations follow one

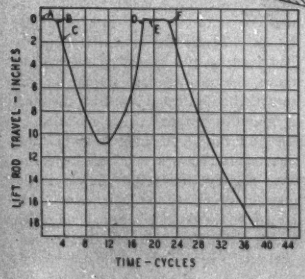


Figure 4 (left). Record of oscillogram showing time in cycles after trip coil is energized at *A* till at *B* contacts part; at *C* arc is interrupted; breaker recloses after partial stroke, and contacts touch at *D*. At *E* the trip coil is again energized, and contacts part in normal time at *F*

Table I. 230-Kv Three-Cycle Breaker Test (Two Grids Per Pole)

(a). One Grid, 1/2 Pole, 66 Kv to Ground, Charging Current, 60 Cycles

Test Number	Interrupted Current (Amperes)	Arcing Time (Cycles)	Main Gap Per Grid (Inches)	*Interrupting Time (Cycles)
1	45	1.0	2.1	2.4
2	45	1.1	2.45	2.5
3	45	1.2	2.8	2.6
4	45	1.3	3.15	2.7
5	45	1.4	3.5	2.8
6	45	1.2	2.8	2.6
7	90	1.6	4.2	3.0
8	90	1.5	3.85	2.9
9	90	1.15	2.6	2.5
10	90	1.3	3.15	2.7
11	90	1.5	3.85	2.9
12	90	1.5	3.85	2.9
13	180	1.3	3.15	2.7
14	180	1.0	2.1	2.4
15	180	1.1	2.45	2.5
16	180	1.4	3.5	2.8
17	180	1.2	2.8	2.6
18	180	1.4	3.5	2.8

(b). Two Grids, 132 Kv to Ground, Charging Current, 60 Cycles

Test Number	Interrupted Current (Amperes)	Arcing Time (Cycles)	Main Gap Per Grid (Inches)	*Interrupting Time (Cycles)
1	90	1.4	3.5	2.8
2	90	1.4	3.5	2.8
3	90	1.3	3.15	2.7
4	90	1.0	2.1	2.4
5	90	1.2	2.8	2.6
6	90	1.0	2.1	2.4

* Based on time of 1.4 cycles from energizing trip coil to parting of contacts.

another with no intentional time delay. These derating factors have been standardized in an attempt to take into consideration certain residual effects, such as temperature of the contact, accumulation of gas and carbon which may make the second interruption more difficult than the first. It is obvious that these residual effects will be minimized in proportion as the arcing time and arc energy are reduced. This result is accomplished in two ways by the multiflow-deion grid type of circuit interrupter. First, the pressure-generating arc and the interrupting arc in the higher-voltage breakers are drawn simultaneously, and second, the arc is deionized, without unnecessary lengthening, by a multiplicity of radially inflowing streams of oil. Figure 5 shows a cross section of the latest design of multiflow deion grid for three-cycle operation at 230 kv. In addition to the normal multiflow deionizing action an auxiliary oil-flow piston is provided to help interrupt line-charging current without delayed restriking and also to provide flushing action when interrupting high fault currents. With regard to the first function of this auxiliary piston, it

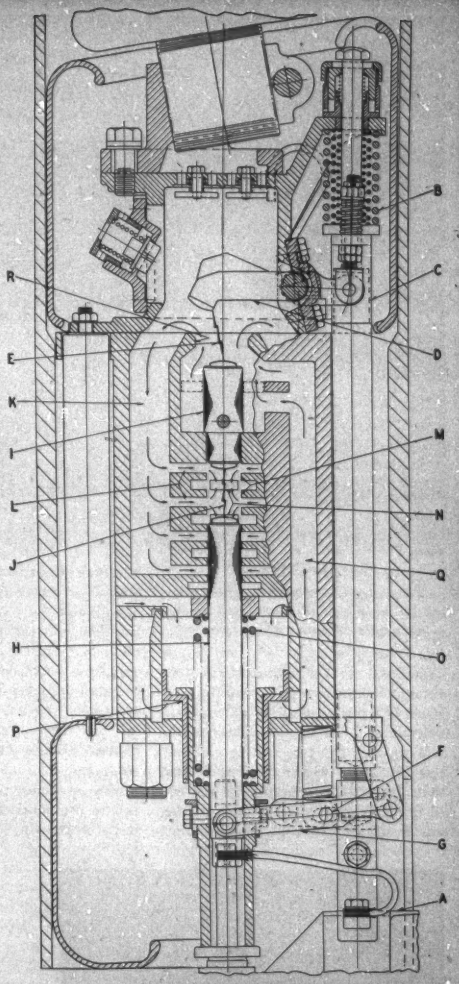


Figure 5. 230-kv multiflow deion grid for three-cycle operating time and 2,500,000-kva rupturing capacity

Tripping of breaker releases main crossarm *A*, allowing springs *B* to move operating-rod *C* down and to rotate contact arm *D*, drawing pressure-generating arc *E*. Simultaneously, pin *F* swings lever *G* downward, pulling contact *H* away from intermediate contact *I* to draw main arc *J*. Pressure from upper arc *E* drives oil through channel *K* to multiflow inlets *L*, deionizing arc in multiorifice structure *M* and sending arc products out vents *N*. Springs *O* push piston *P* downward to provide supplementary oil flow for low-current arc interruption, flowing oil through channel *Q* to orifice *R* in upper gap and then to main flow channel. Back pressure from high-current arcs stops piston until arc is interrupted, when completion of stroke sends flushing oil flow through grid

is well known that successive restriking during the interruption of transmission-line-charging current or the charging current to a large capacitor installation may, under unfavorable conditions, give rise to excessive overvoltage. However circuit breakers equipped with multiflow deion grids, which without piston may show one or occasionally two restrikes, actually did not develop more than twice normal voltage on field tests.

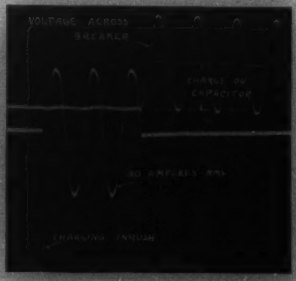


Figure 6. Oscillogram of charging current interruption at 66 kv on 230-kv three-cycle multiflow deion grid unit

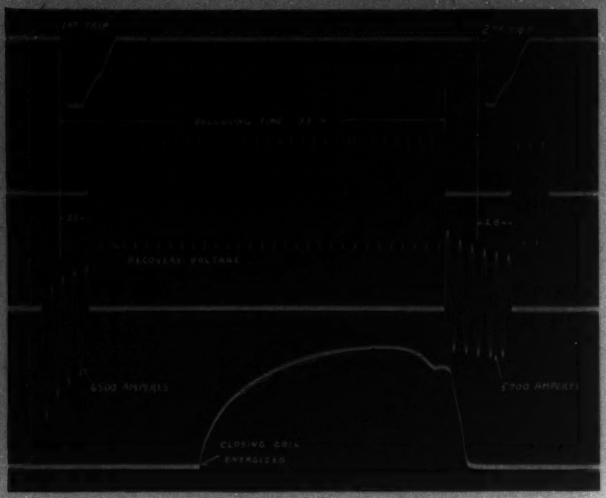


Figure 7. Oscillogram of 230-kv multiflow deion grid interruption at 132 kv to ground on 35-cycle reclosing duty

Fault equivalent to 2,500,000 kva, three phase, opened twice with interrupting time less than three cycles on each tripping operation

Transients of this magnitude may be encountered in any case during the energizing of a line or interrupting fault currents.

When only two interrupting units per pole for 230 kv were used, it was found that the contact separation at the end of one-half cycle after contact parting was insufficient to hold double normal voltage even with the gap completely filled with clean oil. The piston was, therefore, arranged with a delayed pickup so that oil flow is not started until after the contacts have opened approximately one inch. At the next current zero, the charging current is extinguished, and the insulation established in the contact gap becomes adequate to prevent restriking of the arc. Note from Figure 5 that the oil flow from the piston is directed through a single orifice in the top break to develop additional dielectric strength in this gap before passing into the channels to the multiorifice structure in the main break. In Table I are listed 18 interruptions of charging currents with 45, 90, and 180 amperes at 66,000 volts across a single grid unit, and also six interruptions of 90 amperes at 132,000 volts across two grids. No delayed restrikes occurred on any of these tests, a typical oscillogram being shown in Figure 6.

When short-circuit currents are interrupted, the pressure developed by the arc within the interrupting unit is greatly

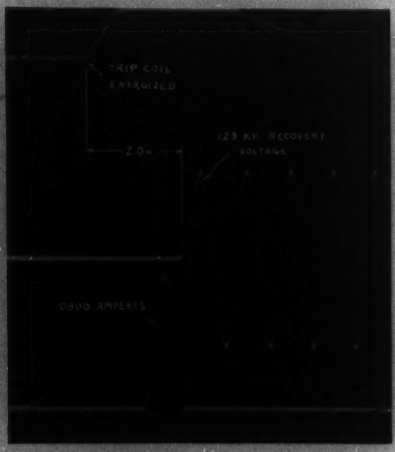


Figure 8. Oscillogram of 230-kv multiflow deion grid interruption at 132-kv-to-ground clearing fault equivalent to 4,300,000 kva, three phase, within two cycles after energizing trip coil using only two grid units per breaker pole

Table II. 230-Kv Three-Cycle Breaker Tests (Two Grids Per Pole)

(a). 132 Kv to Ground, 35-Cycle Reclosing Duty Cycle

Test Number	Interrupted Current (Amperes) 1st Interruption	Interrupted Current (Amperes) 2nd Interruption	Interrupting Time (Cycles) 1st Interruption	Interrupting Time (Cycles) 2nd Interruption	*Reclosing Time (Cycles)
1	4,050	4,050	2.6	2.6	33
2	3,950	3,800	2.8	2.8	32
3	4,150	4,150	2.8	2.8	33
4	6,500	5,700	2.5	2.8	33
5	6,200	5,700	2.8	2.9	33
6	6,200	5,600	2.3	2.9	34
7	3,350	2,900	2.8	3.0	33
8	3,500	3,050	2.8	3.0	33

(b). 132 Kv to Ground, Single Opening Tests

Test Number	Interrupted Current (Amperes)	Interrupting Time (Cycles)	Equivalent 230 Kv, Three-Phase Kva
1	5,300	2.35	2,100,000
2	5,600	2.3	2,220,000
3	5,300	2.5	2,100,000
4	6,200	2.2	2,450,000
5	10,900	2.0	4,300,000
6	8,800	2.4	3,500,000
198 Kv to Ground (Corresponds to Ungrounded Line Condition)			
7	4,100	2.9	1,620,000
8	4,600	3.0	1,820,000
9	6,300	2.9	2,500,000

* Time from initially energizing trip coil to re-establishment of circuit on reclosing stroke.

Table III. 230-Kv Five-Cycle Breaker Tests

132 Kv to Ground, 35-Cycle Reclosing Duty Cycle

Test Number	Interrupted Current (Amperes) 1st Interruption	Interrupted Current (Amperes) 2nd Interruption	Interrupting Time (Cycles) 1st Interruption	Interrupting Time (Cycles) 2nd Interruption	*Reclosing Time (Cycles)
1	2,100	1,800	2.9	3.8	31.5
2	2,100	1,900	3.3	3.0	31.0
3	2,050	1,850	3.4	4.0	31.5
4	5,050	3,850	3.0	3.6	32.5
5	4,650	3,900	3.0	3.1	32.0
6	5,050	3,800	3.0	3.8	32.0
7	7,050	5,500	2.8	3.2	31.5
8	7,000	5,600	2.9	3.6	31.5
9	6,600	5,400	2.9	3.4	31.0

* Time from initially energizing trip coil to re-establishment of circuit on reclosing stroke.

in excess of the spring pressure provided behind the small oil-flow piston. The piston, therefore, does not function during the arc-rupturing process, but, after the circuit has been cleared and the pressure within the unit falls to a relatively low value, the piston then completes its delayed stroke, scavenging the entire arcing space in both contact breaks with a flow of clean oil. Even on a 20-cycle reclosing duty cycle there is sufficient time for this action to be completed so that when the breaker is reclosed, the deion grid is in substantially the same condition as it would be on an initial interruption.

The oscillogram shown in Figure 7 is rather remarkable in that it shows what is believed to be the first interruption of a current corresponding to a three-phase fault of 2,500,000 kva at 230 kv on a 35-cycle reclosing duty cycle, each interruption being accomplished in less than three cycles from energizing the trip coil. Of particular interest is the fact that this test was made with only two interrupting units in a 72-inch tank. This was one of a series of eight consecutive high-power reclosing tests listed in Table II. Also included in this table are nine tests showing the interrupting performance on single opening operations with 132 kv and with 198 kv across a single pole. The interruption of 10,900 amperes shown in Figure 8 is equivalent to a three-phase grounded fault of 4,300,000 kva, this tremendous power being cleared in the remarkably short time of only 2.0 cycles after energizing the trip coil. The 198-kv tests followed without examining the contacts, which were found at the end of the series to have suffered surprisingly little deterioration with considerable life still remaining.

In Figure 9 is the oscillogram of a 35-cycle-reclosing-duty-cycle test on a 230-kv breaker using a multiflow deion grid for five-cycle interrupting time. This grid shown in Figure 10a, differs from the three-cycle design in that there is no multiplying lever system for the moving contact and no auxiliary piston is provided for low current interruption or scavenging action. The excellent performance illustrated by the series of tests in Table III gives evidence that on the 35-cycle reclosing duty cycle, and, with relatively high-speed arc extinction, highly satisfactory performance is obtained.

However, for the 20-cycle reclosing duty cycle, insufficient time is available for the gas produced from the first interruption to be dissipated completely before the breaker is reclosed, and without the flushing action of the piston there would be a tendency, particularly in the higher-voltage breakers, for the arc to sparkover through the contact gap during the closing part of the stroke and impair the interrupting effectiveness of the second operation.

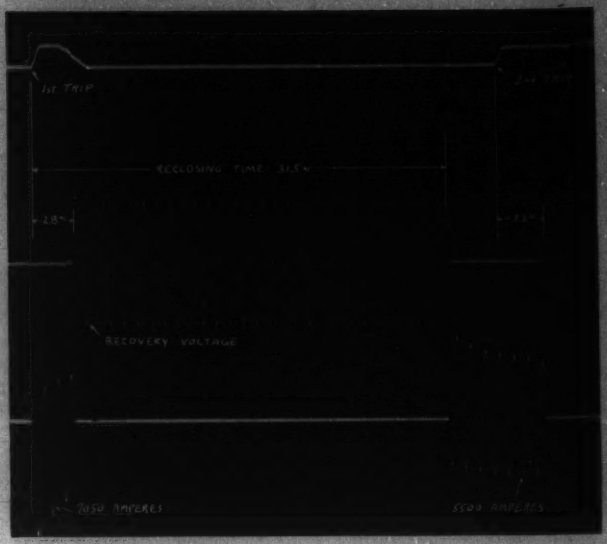


Figure 9. Oscillogram of 230-kv five-cycle multiflow-deion-grid breaker pole-unit opening fault at 132 kv to ground, equivalent to 2,800,000 kva, three-phase, on 35-cycle reclosing duty

At 138 kv the voltage gradient during a closing operation is considerably less than in a 230-kv breaker, and satisfactory reclosing performance has been obtained without a special oil-flushing arrangement. As far back as two years ago, field tests were made on a 132-kv oil circuit breaker with an older design of deion-grid contact operating on a 30-cycle reclosing duty.[3] These tests were made at currents up to 3,000 amperes or approximately 750,000 kva.

The multiflow deion grids for five-cycle service at 138 kv utilize the simplified consecutive contact-opening design illustrated by Figure 10b. A special laboratory test connection was used, supplying 44-kv three-phase power to the single-pole unit, the third phase being brought into the breaker moving contact crossbar by a flexible connection fastened to the bottom of the tank. In this way 44 kv was applied to the deion grid on each terminal, the two in series normally being subjected to 76 kv, or line-to-ground potential on a 132-kv system. The oscillogram in Figure 11 shows a short-circuit current of 9,000 amperes successfully interrupted on a 20-cycle-reclosing duty-cycle test corresponding to approximately 2,250,000 kva. The arcing time on both of these tests was approximately three cycles. No better evidence of the exceptionally low arc energy and gas generation in the multiflow deion grids under short-circuit conditions would seem to be required than the excellent results obtained on this very severe rupturing duty. However, a further striking demonstration of the low stress in the breaker tank was obtained by balancing a $^1/_4$-inch bolt six inches long on its head on a board clamped in a

Table IV. 138-Kv Five-Cycle Breaker Tests

44 Kv Applied to Grid on Each Terminal

Test Number	Interrupted Current (Amperes)		Interrupting Time* (Cycles)		Equivalent 132 Kv, Three-Phase Kva
	Grid A	Grid B	Grid A	Grid B	
1	5,300	3,900	4.3	4.6	1,220,000
2	5,800	4,200	4.6	4.9	1,340,000
3	5,500	7,500	4.3	4.0	1,720,000
4	6,300	7,500	4.5	4.2	1,720,000
5	5,800	7,500	4.3	4.6	1,720,000
6	8,000	8,900	4.1	4.9	2,050,000
7	8,000	9,200	4.1	4.2	2,100,000
8	9,200	8,900	4.3	4.5	2,100,000
9	10,300	11,500	4.3	4.5	2,650,000
10	9,700	11,500	4.5	4.7	2,650,000
11	18,300	15,500	4.3	4.1	4,300,000

* Based on time of 2.3 cycles from energizing trip coil to parting of contacts.

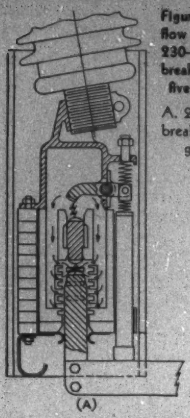
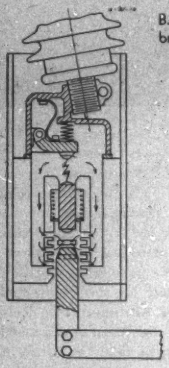


Figure 10. Multiflow deion grids for 230-kv five-cycle breaker and 138-kv five-cycle breaker

A. 230-kv five-cycle breaker, multiorifice grid assembly

(A)



B. 138-kv five-cycle breaker, multiorifice grid assembly

(B)

level position on top of the breaker tank. Single opening tests were carried up to short-circuit currents of as high as 18,300 amperes (see Table IV) corresponding to a three-phase fault of 4,200,000 kva at 132 kv, without the steel bolt toppling over.

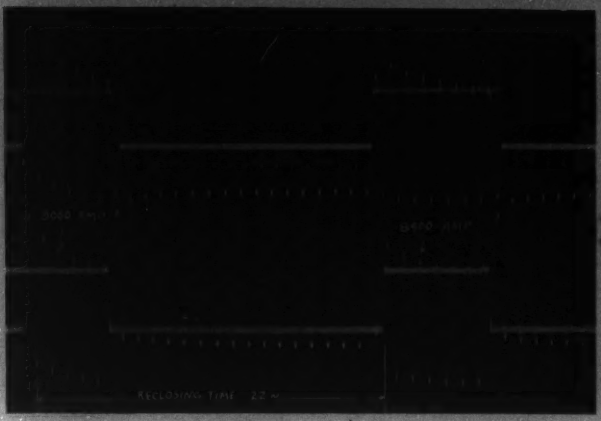


Figure 11. Oscillogram of 138-kv five-cycle multiflow-deion-grid-breaker pole-unit opening fault at 44 kv across each unit equivalent to 2,250,000 kva, three-phase, reclosing within 22 cycles for second tripping operation

Conclusion

As a result of extensive design and testing of high-voltage oil circuit breakers suitable for rapid reclosing duty cycles, the following general conclusions may be drawn:

1. If the recently developed multiflow-deion-grid type of contacts is used, it appears practical to build high-voltage oil circuit breakers of maximum kilovolt-amperes with structural dimensions determined almost entirely by the electrical-insulation requirements.

2. Using a small auxiliary oil-flushing piston, a 230-kv breaker has been designed which is capable of interrupting line-charging current with a minimum of restriking.

3. The low arc energy of the multiflow interrupters makes them particularly suitable for high-capacity oil circuit breakers rated from 115 kv to 230 kv applied on rapid reclosing duty cycles.

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Reclosing of Single Tie Lines Between Systems

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THE urgent necessity for pooling reserve generating capacity has accentuated the importance of single tie-line interconnections equipped with high-speed reclosing breakers. In many cases faults on a single tie line between two sytems can be cleared, and the line can be reclosed with the same reliability that would be obtained if two lines were used without high-speed reclosure. Where a single tie line is used to transmit power between two systems the line must be reclosed fast enough, following a fault, so that synchronism is maintained. Further, the resultant power surges and voltage dips should not cause excessive shock to the system. A brief review of system performance during a reclosing cycle is presented to outline the factors that are involved.

Many practical cases have been analyzed to determine the transient-stability limits for successful reclosure of single tie lines between steam-generating stations. These studies covered a wide range of generating capacities, amount of power transfer, various transmission voltages, and distances between systems. These data are shown in curve form which should be quite useful in determining the feasibility of reclosing and as a guide to the type of commercially available equipment best suited for a specific case.

System Performance During a Reclosing Cycle

In order to visualize readily what happens during a complete reclosing cycle, it is convenient to divide the sequence of operation in four steps, as follows:

1. The initial condition (steady state prior to fault).
2. The fault condition.
3. The fault-cleared condition (breaker open or de-energized period).
4. Condition after breakers are reclosed.

The sequence of events which take place during the reclosing cycle causes the electric outputs of the generators to differ from their respective prime-mover inputs. These changes result in swings of the rotors, the magnitudes of which are determined by the specific system and machine characteristics and the operating conditions. Figures 1, 2, and 3 illustrate a typical case of successful reclosure following a fault on a single tie line. If reclosing had not been applied, in order to transmit firm power between the systems, two lines with a total of four breakers and control equipments would have been required. This example will be recognized as the familiar transient-stability problem in which the rotor positions and system voltage and current changes are obtained by well-known step-by-step stability calculations.[1,2,3]

It is evident that, for any particular problem of tie-line reclosing involving a specific system, the factors affecting the transient-stability problem, and thus the choice of switching and control equipment, depend upon the electric-power output of the synchronous machines during the four periods in the reclosing cycle and the duration of these periods. The power relations can be obtained either analytically or preferably by a-c network-calculator solution of the electrical networks involved.

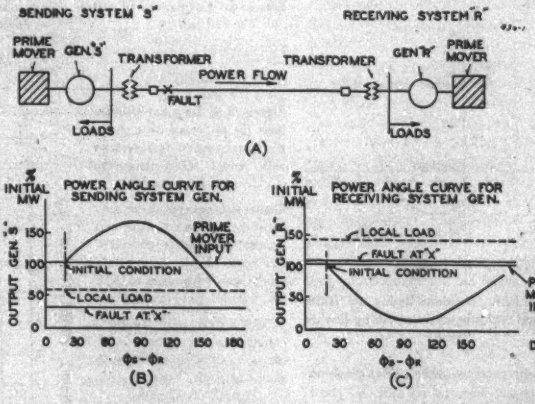

Figure 1. Power-flow characteristics of two systems connected by a single tie line

A. System diagram

B. Power-angle curves of the sending system for normal three-phase fault and line-open conditions

ϕ_S = rotor phase angle of the sending-system generators

ϕ_R = rotor phase angle of the receiving-system generators

C. Same as B except for receiving system

Gain in System Performance With Single-Pole Switching

Consideration of single-pole switching presupposes that the transformer banks at both ends of the tie line are grounded solidly or through low values of impedance. The protective and reclosing relays are arranged to trip and reclose only those poles necessary to clear the fault. The unfaulted wire or wires and ground are available for transmitting power and maintaining voltage during the period when the faulted wire or wires are de-energized. Since the majority of faults do not involve all three wires, single-pole switching in many cases will afford improved system performance.

Figure 4 shows a comparison of the phase-angle swings for three single-pole (individually operated) versus three-pole (gang-operated) breakers for various types of faults in a typical system. For a three-phase fault (Figure 4*A*) all three poles have to be opened to clear the fault so that there is no comparison between

Paper 44-30, recommended by the AIEE committees on power generation and power transmission and distribution for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted November 9, 1943; made available for printing December 2, 1943.

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The authors express appreciation for the assistance of H. P. Peters, D. C. Harker, and R. B. Squires in the detail calculations and in the operation of the a-c network calculator.

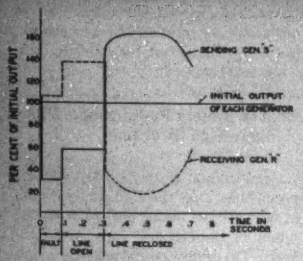


Figure 2. Electric-power output of generators for a typical reclosing cycle of the tie line of Figure 1

The fault near the sending end of the line is cleared in 0.1 second, and the line reclosed in 0.3 second

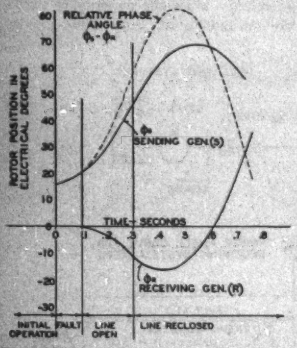


Figure 3. Rotor positions during the fault-clearing and reclosing cycle of the tie line of Figure 1

three single-pole or three-pole switching for this case. Figures 4*B* and 4*C* show considerable improvement in system operation with single-pole switching, as indicated by the smaller swings in phase angle of the generators.

Another measure of the severity of the disturbance to the system is the drop in voltage on the load busses. In general, the voltages decrease with the increase of the phase-angle difference between the two systems. For the case of Figure 4 the voltage at maximum swing at the receiver load bus in per cent of normal is shown in Table I.

Determination of the Type of Switching to Be Used for Specific Applications

The question to be decided in the determination of the proper choice of reclosing equipment is what type of commercially available reclosing breakers and control should be used when a desired amount of

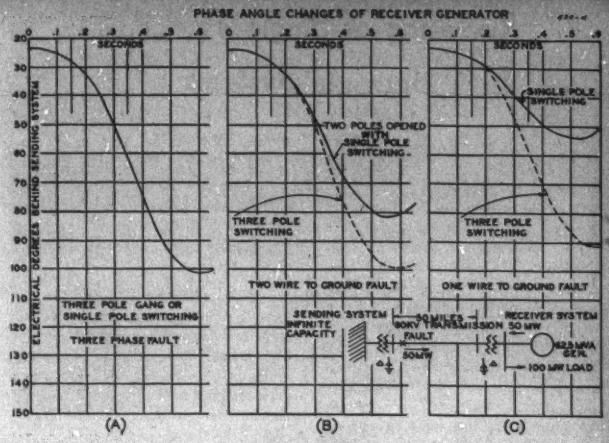


Figure 4. Comparison of system swings following fault, clearing of fault, and reclosing of a single tie line

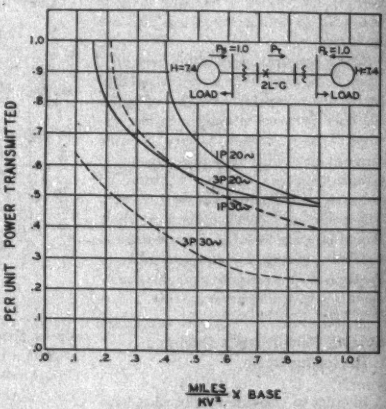
Fault cleared in nine cycles (0.15 second), and the line reclosed in a total time of 21 cycles (0.35 second)

Figure 5. Transient-stability limit for reclosing of a single tie line between two systems with equal steam-generating capacity connected

Base equals generating capacity in either system. Per unit power transmitted is referred to this base. Faults are double line to ground cleared in 0.15 second (nine cycles)

3*P*30~ = three-pole gang-operated breakers reclosed in 30 cycles. 3*P*20~ = three-pole gang-operated breakers reclosed in 20 cycles

1*P*30~ = individual pole-operated breakers reclosed in 30 cycles. 1*P*20~ = individual pole-operated breakers reclosed in 20 cycles



power is to be transmitted a given distance over a single line between two systems. Figures 5, 6, and 7 will be found directly useful in answering this question in a great many cases. These curves present the results of investigations of over 100 practical solutions. Each curve shows the transient-stability limits based on two line-to-ground faults for various ratios of power transmitted to size of the system plotted against a measure of the electrical length of the transmission line. There are four curves in each figure, one for each of four commercially available reclosing-breaker schemes. In addition on Figure 7 there is shown the curve for three-pole 35-cycle reclosing. It is recognized that, at some of the higher-transmission voltages, this rather than 30 cycles is standard. The areas to the left and below these curves are regions below the transient-stability limit where successful reclosure would be obtained. The areas to the right and above the curves are above the transient-stability limits for the respective types of reclosing equipment.

The use of these curves is illustrated in Table II where several typical examples are shown. The choice of which group of curves to use depends on the relative sizes of the sending and receiver systems.

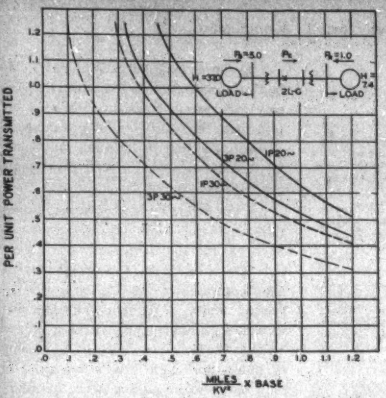


Figure 6. Transient-stability limit for reclosing of a single tie line between two systems with the steam-generating capacity of the sending system five times that of the receiving system

Base equals generating capacity in receiver system. Per unit power is referred to this base. Faults are double line to ground cleared in 0.15 second (nine cycles)

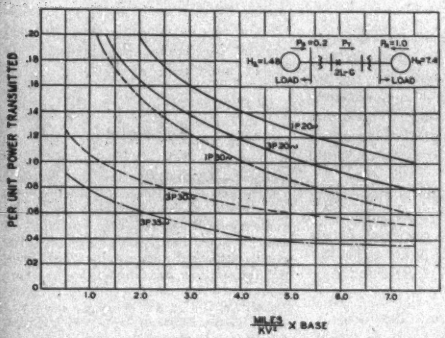


Figure 7. Transient-stability limit for reclosing of a single tie line between two systems with the steam-generating capacity of the receiving system five times that of the sending system

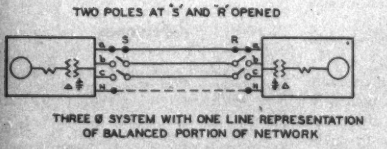
Base equals generator capacity in receiving system. Per unit power transmitted is referred to this base. Faults are double line to ground cleared in 0.15 second (nine cycles)

Table I

Type of Fault	Per Cent of Normal System Voltage: Three-Pole Switching	Per Cent of Normal System Voltage: Single-Pole Switching
Three phase	73.5	73.5 (all 3 poles open)
Two lines to ground	74.5	82 (2 poles open)
One line to ground	78.0	93 (1 pole open)

Figure 5 is used if they are equal substantially. Figure 6 is used if the sending-end connected capacity is in the order of five times that of the receiver. Figure 7 is used if the receiver system has five times the capacity of the sending system. For other relative sizes interpolation is possible.

The data plotted on Figures 5, 6, and 7 were obtained from transient-stability solutions of examples with constants and initial operating conditions so chosen that the results applied to a large range of systems. The initial operating conditions for each point on the curves were obtained by establishing voltage and power flows that could be expected reasonably under practical operating conditions. The base selected was equal to the kilowatt capacity of the receiver system. The total amount of generation in either system was assumed to be made up of the necessary number of 1,800-rpm 80 per cent power-factor machines operating at full kilowatt load and excitation as required. The constants of the machines used were $H=7.4$, $x_d{}^1=0.23$, $x_2=0.15$, $r_1=0.900$, and $r_2=0.035$. The shunt loads were assumed to be at 85 per cent power



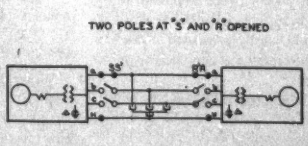
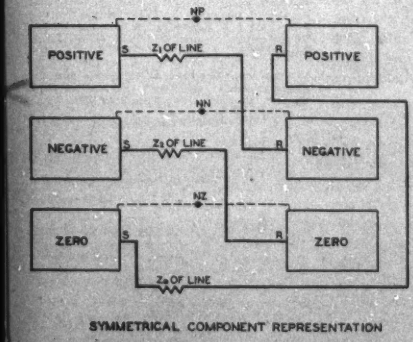


Figure 8. Electrical representation of condition following the clearing of a fault on a single tie line

A (left). Two-line-to-ground fault on a short line (negligible charging capacity)

B (right). Two-line-to-ground fault on a long line (charging capacity included)



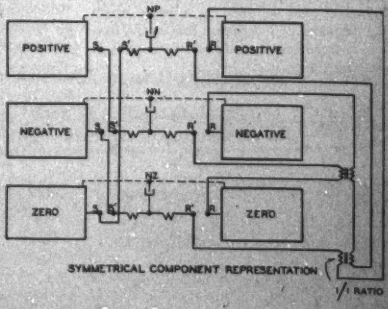


Table II. Examples of Use of Figures 5, 6, and 7 to Determine Suitable Switching for Specific Cases

PS = Generation at Sending End (Megawatts)
PR = Generation at Receiving End (Megawatts)
PT = Maximum Power to Be Transmitted (Megawatts)

Case Number	Known System Characteristics					Per Unit PT	Miles / K_y^2 × Base	PS/PR	Use Figure	Synchronism* Maintained With Following Types of Reclosing
	PS	PR	PT	Kilovolts	Miles					
1	50	50	25	69	40	0.5	0.42	1	5	1 pole, 30 cycle 3 pole, 20 cycle 1 pole, 20 cycle
2	100	100	60	110	100	0.6	0.83	1	5	None
3	250	50	25	69	40	0.5	0.42	5	6	3 pole, 30 cycle 1 pole, 30 cycle 3 pole, 20 cycle 1 pole, 20 cycle
4	500	100	70	110	100	0.7	0.83	5	6	1 pole, 20 cycle
5	20	100	15	69	50	0.15	1.05	0.2	7	1 pole, 30 cycle 3 pole, 20 cycle 1 pole, 20 cycle
6	100	500	70	110	90	0.14	3.72	0.2	7	1 pole, 20 cycle

* When more than one type of reclosing is suitable so far as maintaining synchronism is concerned, the final choice will depend on other factors, such as the severity of the disturbance as measured by the voltage dips and power surges.

factor. The line regulation was adjusted to ten per cent. In certain cases this required that reactive kilovolt-amperes be furnished by the receiver system in excess of the capacity of the receiver generators. In these cases the additional reactive kilovolt-amperes required were assumed to be supplied by synchronous condensers. The inertia of these condensers was not included in the swing calculations as it usually was so small as to be negligible, and, even where condensers of considerable size were used, the omission of their inertia would tend to give pessimistic results.

Standard step-up and step-down transformers with per unit reactance of 0.085 were used. They were assumed to be connected delta-wye with the neutrals on the high side solidly grounded. The size of the transformers was equal to the power transmitted.

The line had the following characteristics:

$x_1 = 0.71$ ohm per mile
$y_1 = 5.8(10)^{-6}$ mhos per mile
$r_0 = 0.45$ ohm per mile
$x_0 = 2.84$ ohms per mile
$r_1 = 0.35$ ohm per mile, or a value which would give 10 per cent loss in the line, whichever gave the smaller value of resistance

In using these line characteristics to obtain systems with practical operating conditions, it was assumed that the line would be operated at approximately unity power-factor loading. This means that the line charging kilovolt-amperes would be about equal to the i^2x consumed in the line.

The transient stability of the systems for the different distances and amounts of power transferred was calculated by obtaining the required power-angle diagrams from a-c network-calculator solution for:

1. The initial and reclosed conditions.
2. Two-wire-to-ground faults as the criterion for transient stability.
3. Two poles open for single-pole-opening breakers (see appendix).
4. Three poles open for gang-operated breakers.

When these power-angle diagrams were used, the usual step-by-step method of calculation was employed to determine the phase-angle swings of the machines for the various types of operation. By varying the length of line with all the other conditions held constant, the critical point was reached where an increase in distance would result in instability, and where shorter distances would prove stable.

Conclusion

The curves on Figures 5, 6, and 7 embody the results of such a multiplicity of practical system transient-stability solutions that they can be used as a guide in choosing the type of reclosing equipment for a single tie line between two steam-generating systems.

An inspection of these curves shows that single-pole switching in many cases offers a marked advantage over three-pole switching from the standpoint of transient stability based on two wire-to-ground faults. Further, additional advantages of single-pole switching accrue because the majority of faults (70 per cent or more) are single line to ground. If only one breaker pole is open, considerable synchronizing power is maintained during the clearing of this type of fault. This results in reduced voltage dips and system oscillations, as illustrated in Table I and Figure 4.

Appendix I

Figures 8A and 8B show the electrical connections of the three sequence networks to represent the unbalanced system conditions obtained by single-pole switching. It may be noted that, where there are shunt connections to the opened line as in Figure 8B, the multiple unbalances so produced are represented by using 1-to-1 ratio transformers in the connection of the networks. These connections have been developed from fundamentals previously described.[4]

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Rectifier-Circuit Duty

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THE usual rectifier unit consists of a transformer with a number of rectifying elements connected to its secondary windings. The rectifying action may be resolved into two parts, namely, the circuit action which is determined by the transformer and the a-c and d-c circuits, and the unidirectional switching action which is performed by the rectifying elements. The circuit action is defined by the number, arrangement, and constants of the circuits connecting the a-c and d-c systems. The switching action consists of connecting the various secondary windings of the transformer to the load circuit at selected intervals during each cycle by means of mercury-arc rectifiers, metallic rectifiers, vacuum tubes, and other types of rectifying elements.

The size and characteristics of the rectifying elements required for any rectifier unit depend upon the current each must carry during the conduction period and the voltage it must withstand during the idle period. Although the rectifying element may control the time at which conduction starts (as, for example, in phase-controlled rectifiers), in other respects it is a passive element, since the voltage and current impressed upon it are determined by the circuit constants. The nature and value of the voltage and current appearing on the rectifying elements, that is, the loading on these elements, may be termed the circuit duty. Conversely, the capability of the rectifying element may be termed the rectifier capacity. The rectifier capacity may be measured in terms of the maximum circuit duty at which it is capable of operating without failure.

These terms may be defined as follows:

1. The rectifier-circuit duty is the voltage and current loading applied to the rectifying element by the rectifier circuit.

2. The rectifier capacity is the maximum loading at which the rectifying element is capable of operating without failure. It may be expressed in the same terms as the circuit duty.

The concept of rectifier-circuit duty and rectifier capacity provides a convenient and useful means for analyzing the action taking place in any rectifier equipment. It permits a division of engineering functions into two parts, one of which deals with the analysis and application of rectifier circuits, whereas the other is concerned with the design and construction of suitable rectifying elements. Such a division of the engineering functions involved in rectifier design is not new but has been employed for some time in the design of small vacuum-tube rectifiers, where the performance of the tube is specified by itself, and the same tube may be used in a wide variety of applications. The effect of circuit upon performance is recognized also in the design and application of metallic rectifiers.

The application of this method of analyzing rectifier action requires a knowledge of the factors which limit the rating of the rectifying elements. Since arc-back behavior is a primary consideration in the performance and rating of mercury-arc rectifiers, and the functional relations between circuit factors and arc-back have not been established fully, this method has heretofore been used only in a very general way. However, a better understanding of the factors which limit rectifier rating is obtained if the circuit duty is determined on the basis of relations between the impressed voltage and current and the occurrence of arc-back, as indicated by studies of the physical action taking place within the rectifier.

It is the object of this paper to present an analysis of rectifier circuits in terms of circuit duty and rectifier capacity, discuss the various factors involved, and compare the various types of rectifier circuits.

Elements of Circuit Duty

It appears axiomatic that the duty on the rectifying elements arises from both the magnitude and the shape of the voltage and current waves, the effect of wave form depending upon the type of rectifying element employed.

Typical voltage and current waves on the rectifying element in a rectifier circuit are shown in Figure 1. A study of the physical processes which take place in the rectifying elements indicates that the circuit duty may be expressed in terms of the following voltages and currents:

Voltage

1. Peak inverse voltage.
2. Rms inverse voltage.
3. Initial inverse voltage.
4. Peak forward voltage.

Current

5. Average current.
6. Peak current.
7. Rms current.
8. Final commutation rate.

Peak Inverse Voltage

The peak inverse voltage is a measure of the maximum dielectric stress applied across the rectifying element during the idle period. Failure from excess voltage may take various forms, such as flashover, puncture of dielectric materials, or excessive glow discharge resulting in arc-back.

Rms Inverse Voltage

The rms value of the inverse voltage appears to be important only in the case of rectifiers having appreciable leakage current during the inverse period, where it provides a measure of the heating resulting from this leakage current. The leakage resistance characteristics of metallic rectifiers (such as the copper-oxide and selenium types) are nonlinear, and an accurate determination of the losses may require weighting factors other than those given by rms values. However, the heating due to the leakage current is usually given in terms of the rms values of the inverse voltage because of the ease with which such values may be determined.

Initial Inverse Voltage

The ionization in a mercury-arc rectifier does not disappear immediately upon the extinction of anode current, and, therefore, some residual ionization is present during the idle period. The amount of the residual ionization is greatest at the beginning of the idle period and decays as a function of time. The action of the

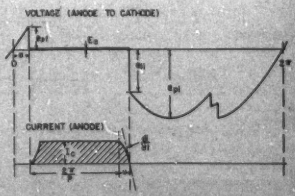

Figure 1. Typical voltage and current waves on rectifying element

Paper 44-41, recommended by the AIEE committee on electronics for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted November 26, 1943; made available for printing December 11, 1943.

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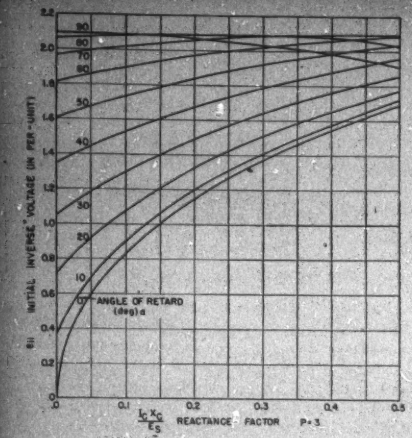


Figure 2. Initial inverse voltage $P=3$

Per unit base is E_{do}

$$\frac{e_{ii}}{E_{do}} = \frac{2\pi}{P} \sin(u+\alpha)$$

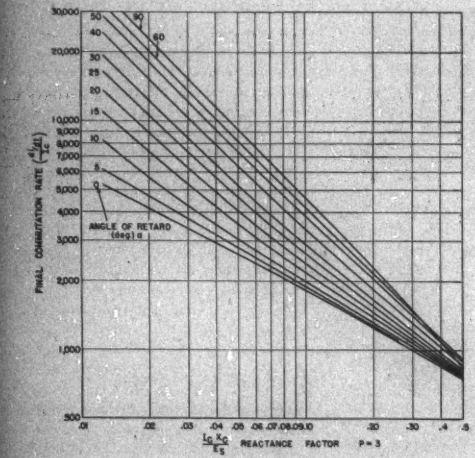


Figure 3. Final commutation rate $P=3$, $f=60$ cycles

Multiply values of $\frac{di}{dt}/I_e$ given on curve by direct current commutated I_e to obtain commutation rate in amperes per second

$$\frac{di}{dt} = \left[\frac{\omega}{\sqrt{2}} \frac{P}{\pi} \sin\frac{\pi}{P}\right] \frac{E_x}{X_c} \frac{e_{ii}}{E_{do}}$$

rectifier circuit results in a sudden application of negative voltage across the rectifying element immediately following conduction. This negative voltage acting upon the residual ionization attracts positive ions to the anode. Since the positive ion bombardment may cause arc-back, the initial inverse voltage is a factor in the duty applied to a mercury-arc rectifier.

Peak Forward Voltage

When a rectifier is operated with the d-c voltage reduced by phase control, a positive voltage is applied across the rectifying element during the latter part of the idle period. This forward voltage imposes a further requirement upon the control characteristics of the rectifying element, since conduction must not occur before the desired firing time.

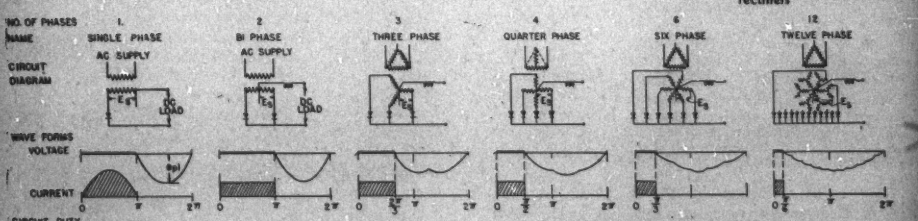
Average Current

The average current passed by the rectifying element is a convenient measure of the duty imposed upon it, since this value bears a simple relation to the load current on the rectifier unit. For this reason the current capacity of the rectifying element is customarily expressed in terms of average current. However, the average current does not bear so definite a relationship to the physical action and physical limitations of the rectifying element as do the peak and rms current values.

Peak Current

The losses resulting from the passage of current are one of the factors which limit the capacity of the rectifying elements. However, the nature of the current limitations in mercury-arc rectifiers is somewhat different from that in other electric apparatus, since failure by arc-back may occur without measurable temperature

Figure 4. Comparison of circuit duty of simple rectifiers



CIRCUIT DUTY	1	2	3	4	6	12
DC VOLTAGE $E_{do}/E_s = 0.45$	0.90	1.17	1.27	1.35	1.41
PEAK INVERSE VOLTAGE $e_{ii}/E_{do} = 3.14$	3.14	2.09	2.22	2.09	2.02
AVG. ANODE CURRENT = 1.00	0.50	0.33	0.25	0.167	0.083
RMS ANODE CURRENT = 1.57	0.707	0.577	0.50	0.408	0.288
PEAK ANODE CURRENT = 3.14	1.00	1.00	1.00	1.00	1.00

*(IN PER-UNIT ON BASE OF LOAD CURRENT I_d)

rise. As the instantaneous arc drop is a function of the instantaneous current, the peak anode current is an important factor in the determination of the loading. Furthermore, the conditions existing in the mercury vapor at the end of the conducting period are a function of the peak current which has passed during conduction, and the peak current, therefore, influences the prob ability of arc-back. In the case of heated cathode rectifiers, the output of the rectifier is limited by the maximum emission which may be obtained from the cathode without damage.

Rms Current

The heating in the leads and other conducting parts of the rectifying element depends upon the rms value of the current.

Final Commutation Rate

The amount of residual ionization present at the beginning of the inverse period depends in large measure upon the rate of reduction of current during the last few degrees of conduction. The final commutation rate is the rate of change of anode current at the instant of extinction and in some cases may be taken as a measure of the amount of residual ionization present in the rectifier at the time that the initial inverse voltage appears across it. Therefore, the final commutation rate is a further element in the duty on the rectifier.

The commutation rate also may be of importance during the initial part of the conduction period when the rate of current build-up exceeds the ionization rate of the rectifier. Under such conditions additional local heating and voltage stresses may be imposed upon the rectifier.

The researches of Kingdon and Lawton[1] have shown that there is a definite relation between the residual ionization and the arc-back frequency. Under certain conditions the frequency of arc-back due to residual ionization is a function of the product of the initial inverse voltage by the final commutation rate. Since arc-backs in mercury-arc rectifiers are caused by many factors, this relationship has not been established fully on commercial rectifiers. However, experience with many rectifier installations indicates that some such relationship does exist.

Determination of Circuit Duty (Circuit Analysis)

The circuit duty may be determined by an analysis of the action in a simple rectifier circuit. The formulas for the various elements of circuit duty for a simple rectifier of P phases follow.

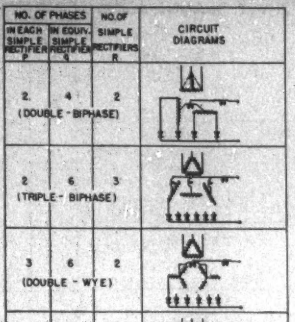


Figure 5. Multiple rectifiers

The peak inverse voltage (e_{pi}) expressed in terms of the theoretical d-c voltage E_{do} is

$$e_{pi} = K \frac{\pi}{P \sin \frac{\pi}{P}} E_{do} \qquad (1)$$

where

K = ratio of secondary voltage across phases to secondary voltage line to neutral (When $P = 3$ the value of K is $\sqrt{3}$, and when $P = 2$, 4, 6, and 12 the value of K is 2)

The rms inverse voltage is not given here but may be determined from the inverse-voltage wave by integration.

The initial inverse voltage (e_{ii}) is given by the expression

$$e_{ii} = \frac{2\pi}{P} E_{do} \sin (u + \alpha) \qquad (2)$$

where

u = angle of overlap and
α = angle of phase retard

The initial inverse voltage for a simple three-phase rectifier is shown in Figure 2.

The peak forward voltage (e_{pf}) is

$$e_{pf} = \frac{2\pi}{P} E_{do} \sin \alpha \qquad (3)$$

The average and rms current passing through the rectifier elements may be expressed in terms of the direct current commutated I_c (peak current) as follows:

$$\text{average current} = \frac{I_c}{P} \qquad (4)$$

$$\text{rms current} = \frac{I_c}{\sqrt{P}} \qquad (5)$$

The final commutation rate (di/dt) may be obtained by differentiating the expression for the commutating current. The resulting value is

$$\frac{di}{dt} = \left[\sqrt{2}\,\omega \sin \frac{\pi}{P}\right] \cdot \frac{E_s}{X_c} \cdot \sin (u + \alpha) \qquad (6)$$

$$= \left[\frac{\omega}{\sqrt{2}} \frac{P}{\pi} \sin \frac{\pi}{P}\right] \cdot \frac{E_s}{X_c} \cdot \frac{e_{ii}}{E_{do}} \qquad (7)$$

where

$\omega = 2\pi f$, f = frequency of supply system
X_c = commutating reactance, ohms line to neutral
E_s = secondary voltage to neutral in rms volts

The variation in final commutation rate with the reactance factor is shown in Figure 3.

The analysis of any of the more complex rectifier circuits is facilitated by breaking them down into their component simple rectifiers. In cases where the rectifier installation has many phases which are displaced so as to obtain an equivalent simple rectifier with many phases, commutations will overlap, and the determination of the initial inverse voltage and final commutation rate becomes more difficult. Although it is possible to analyze such circuits, in general, it may be more practical to determine these elements of circuit duty by direct measurement.

Circuit Constants Versus Circuit Duty

Rectifier specifications covering rating and operating characteristics usually include the following factors:

1. Connection diagram (number of phases of equivalent simple rectifier).
2. D-c voltage.
3. Load current.
4. Voltage regulation (reactance of transformer and a-c system).
5. Amount of phase control.

The preceding factors, while they are very useful in the description of the complete equipment, do not provide much information with regard to the choice of rectifying elements. However, these factors bear a functional relationship to the elements of circuit duty and serve

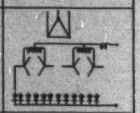
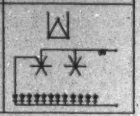
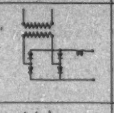
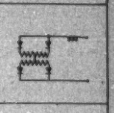
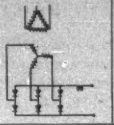
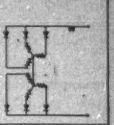
NO. OF PHASES IN EACH SIMPLE RECTIFIER p	NO. OF PHASES IN EQUIV. SIMPLE RECTIFIER q	NO. OF SIMPLE RECTIFIERS R	CIRCUIT DIAGRAMS
3	6	4	
(QUADRUPLE-WYE)			
6	6	2	
(DOUBLE-SIX PHASE)			

Figure 6. Parallel rectifiers

Figure 7. Double-way rectifiers

NO. OF PHASES IN EACH SIMPLE RECTIFIER p	NO. OF PHASES IN EQUIV. SIMPLE RECTIFIER q	NO. OF SIMPLE RECTIFIERS R	CIRCUIT DIAGRAMS	EQUIVALENT SEC. CIRCUIT
2	2	2		
3	6	2		

as a basis for the determination of the circuit duty imposed on the rectifying elements. The relationship between these factors and circuit duty is shown by the following examples:

Simple Rectifiers

The wave form of the voltage and current on the rectifying elements for various simple rectifiers is shown in Figure 4. The circuit duty for each of these connections may be calculated by the foregoing formulas.

Multiple Rectifiers

Most rectifier installations use a combination of simple rectifiers in multiple, parallel, cascade, or series in order to obtain the most economical arrangement and the desired operating characteristics. Such circuits may be broken down into component simple rectifiers and circuit duty determined from the foregoing formulas. A number of commonly used multiple rectifier circuits is shown in Figure 5 and two parallel rectifier circuits in Figure 6.

Double-Way Rectifiers

Double-way circuits may be reduced to the form of simple rectifiers in cascade or series. Figure 7 shows two frequently used double-way rectifier circuits with the equivalent cascade or series circuits.

Comparison of Three Six-Phase Circuits

A comparison of the circuit duty incurred in three different six-phase rectifier circuits having the same rating and the same regulation characteristics is shown in Figure 8. The values given in this comparison are based on a six-anode rectifier rated 1,500 kw at 600 volts and 2,500 amperes. The theoretical voltage for each of the three cases is $E_{do}=650$, and the voltage regulation due to transformer reactance is assumed to be $E_x/E_{do}=0.035$. With the usual transformer resistance such a rectifier would have a normal regulation of approximately five per cent. It is assumed that the rectifier is operated with no phase retard.

Effect of Reactance

The effect of reactance upon the initial inverse voltage and final commutation rate is shown in Figure 9. With reference to this figure, the solid curves are the same as those for the delta double-wye rectifier circuit in Figure 8 and for a rectifier having a voltage regulation $E_x/E_{do}=0.035$. The dotted curves give the values for a rectifier having twice the transformer reactance and, therefore, twice the value of regulation. The effect of increased reactance is to increase the initial inverse voltage and to reduce the commutation rate.

Effect of Phase Control

The effect of phase control upon the initial inverse voltage and final commutation rate is shown in Figures 2 and 3. The application of phase control increases both the initial inverse voltage and the final commutation rate. Experience shows that the probability of arc-back is increased when a rectifier is operated with phase control.

Selection of Rectifier Circuits

The choice of the rectifier circuit for any specific application is based on considerations involving wave form, power factor, regulation, and efficiency requirements. The rating and characteristics of the rectifying elements available must be considered also.

Wave Form

The number of phases of the rectifier circuit is selected so as to obtain a suitable wave form. Most rectifier equipments in the higher ratings consist of a number of rectifier units displaced in phase so as to reduce the magnitude of the harmonics in the a-c and d-c systems. The minimum number of phases is usually six, and the number increases to 12, 24, 36, and so forth for the larger installations.

Regulation

The inherent regulation of the rectifier is determined primarily by the reactance of the rectifier transformer. The value of reactance is chosen so as to obtain the desired regulation characteristic.

Another important consideration in the selection of transformer circuit reactance is the magnitude of fault current under d-c short circuit and arc-back. The fault current is a primary factor in the circuit duty under short-circuit conditions, and the circuit reactance must limit the current to a value less than the fault-current capacity of the rectifying elements.

The effect of type of circuit upon the transformer reactance and d-c short-circuit current is shown in the comparison of three six-phase circuits in Figure 8.

In 12-phase circuits the transformer reactance and the d-c short-circuit current depend upon the arrangement of the transformer windings. For example, by interlacing the secondary windings of the quadruple zigzag transformer shown in Figure 10*b*, the values of transformer reactance will be twice and of d-c short-circuit current half those obtained on the quadruple-wye transformer shown in Figure 10*a* for the same voltage regulation.

One advantage of the double-way circuit shown in Figure 7 is that there is no d-c feedback during arc-back, since this circuit is equivalent to two simple rectifiers in series.

Efficiency

Best utilization of transformer windings is obtained usually with a circuit consisting of a number of simple three-

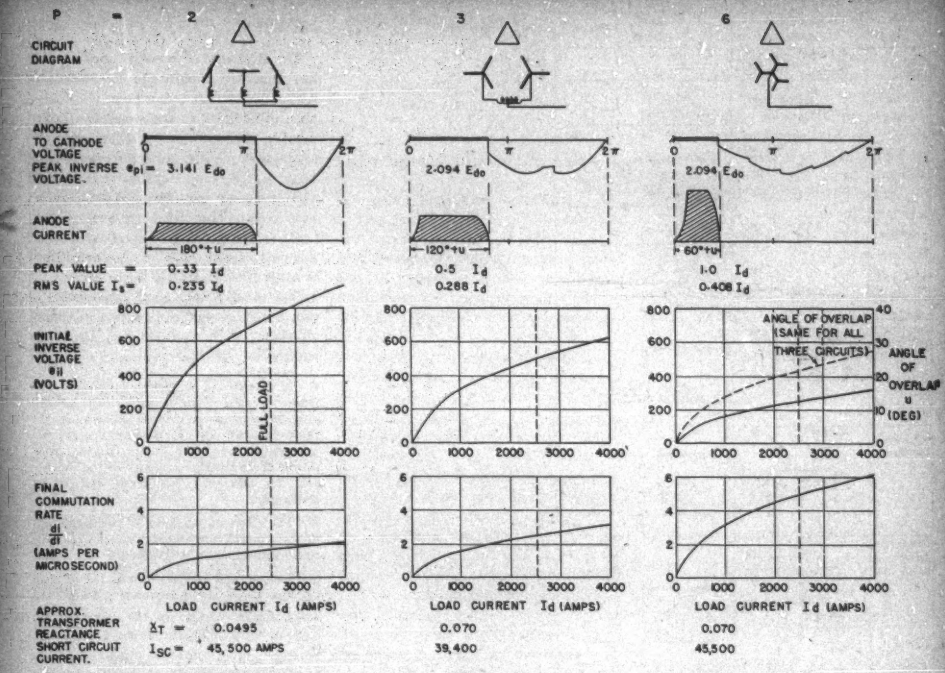


Figure 8. Comparison of three six-phase circuits for rectifier rated 600 volts, 1,500 kw

phase rectifiers arranged in multiple and parallel combinations, and, for this reason most rectifier installations employ this type of circuit. These circuits also result in a good utilization on the rectifier.

A six-phase fork connection is used often on certain sizes of rectifiers. Some of its advantages are elimination of the interphase transformer, simplification of the control circuit, and elimination of the possibility of transformer unbalance. However, with this circuit, the peak anode current has twice the value obtained in a double-wye circuit, and the rectifier capacity is reduced, while the arc losses are increased. Tests on six-anode ignitron rectifiers show that the full-load arc losses are approximately 8 per cent greater when operating fork-connected than when operating double-wye.

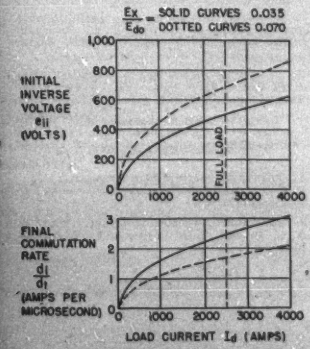

$\frac{E_x}{E_{do}}$ = SOLID CURVES 0.035
DOTTED CURVES 0.070
INITIAL INVERSE VOLTAGE e_{ii} (VOLTS)
FULL LOAD
FINAL COMMUTATION RATE $\frac{di}{dt}$ (AMPS PER MICROSECOND)
LOAD CURRENT I_d (AMPS)

Figure 9. Effect of reactance on initial inverse voltage and final commutation rate

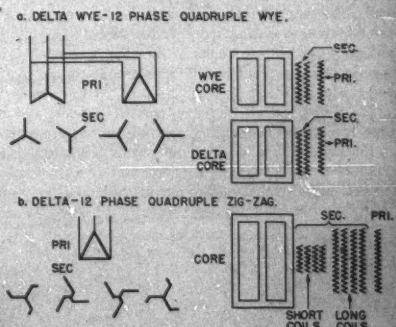


Figure 10. Quadruple-wye and quadruple-zigzag circuits

Special Circuits

A number of circuits providing a variety of operating characteristics and different modes of operation is shown in Figure 11.

The first of these is a single-phase rectifier circuit having three different modes of operation. In this circuit the mode of operation is determined by the constants of the d-c load. The voltage and current wave forms for the different cases are shown.[2]

The second circuit is a simple biphase

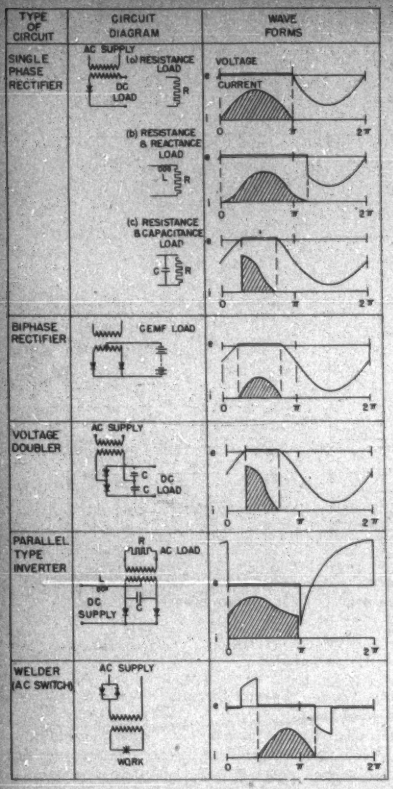


Figure 11. Special circuits

rectifier operating with a counter electromotive-force load.[3] In the usual mode of operation for this circuit the load current is intermittent. The range of intermittent operation depends on the circuit constants and the amount of phase control.

The third circuit shows a voltage doubler.[4] This is a double-way circuit, and the voltage and current waves across the rectifying element are similar to those for the single-phase rectifier with resistance and capacitance load.

The fourth circuit shows a parallel-type inverter.[5] The voltage and waves of the parallel-type inverter differ from those for most rectifiers in one important respect, namely, the voltage across the rectifying element is negative for only a short part of the inverse period immediately following conduction. During the remainder of the conduction period a positive voltage is applied across the rectifying element. This type of voltage wave is common to most inverter circuits and imposes a duty which differs from that of the usual rectifier.

The fifth circuit shows a welder or a-c switch.[6] This type of circuit employs two rectifying elements connected so as to permit current flow in opposite directions, and the combination operates as an a-c switch. It has found widespread application in resistance welding.

The foregoing examples are only a few of a large variety of new applications.

Conclusion

The diversity of rectifier applications has increased rapidly during the past few years, so that today there are available, in addition to the rectifier, a large number of power electronic devices, such as rectifiers with voltage control, inverters, frequency changers, welders, and electronic switches. With such a wide variety of rectifier applications the problem of matching the performance of the circuit with that of the rectifying element assumes greater importance.

Several advantages are obtained by expressing the rectifying action in terms of circuit duty and rectifier capacity, namely:

1. A division of engineering functions is made possible. The analysis, calculation, and selection of rectifier circuits and rectifying elements for different applications is one project while the design, testing, and rating of rectifying elements is the other; and the two may be carried out independently.

2. The elements which must be considered in determining the capacity of all types of rectifying elements are defined.

3. The method for determining the limitations of the rectifying elements is indicated.

4. A common basis for the rating of all types of rectifying elements is provided.

5. The application of any rectifying element to a wide variety of circuits is facilitated.

It is hoped that this method of analysis may be extended to all types of circuits using rectifiers, and that a standard basis for rating all types of rectifying elements may be developed.

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A Versatile Power-Line-Carrier System

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POWER-LINE carrier has kept pace with the swift progress of the electronic art during the last several years. This progress has been due mainly to the stimulus injected by the war effort. In most of the specialized fields of electronics, the advancement was necessitated and promoted strictly for military purposes. Power-line carrier, however, was and is the soldier of the home front. Its duties have been expanded to include as many functions as possible consistent with reliability, economy, and convenience. The economic feature is especially significant now, since, during wartime emergencies, the material resources of the nation are allotted, and properly so, to those agencies concerned with the battle front. Material for new power lines, new generating equipment, new telephone lines, and for other similar programs of expansion is therefore not generally available. However, power-line carrier comes to the rescue and effectively provides additional circuits and higher power-handling capacity for existing installations.

Functions of Power-Line Carrier

For over two decades carrier frequencies have been used on power transmission lines to provide a channel between generating plants, substations, and similar terminals for communication, and, more recently, for high-speed relaying. However, with the development and expansion of large interconnected power systems, the available carrier channel has been used for a number of other functions. In fact, the additional services provided by a carrier system often have been the deciding factor in justifying its installation. A typical list of functions would include the following:

1. Carrier relaying (and emergency communication).
2. Telemetering and load control.
3. Supervisory control.
4. Remote or transferred tripping.
5. Communication.

It is the purpose of this paper to show how a carrier channel can be utilized to provide these additional functions by means of audio tone modulation of the carrier signal.

Advantages of Tone Modulation

A power-line-carrier installation employing unmodulated carrier can be used for only one function at a time, such as relaying, telemetering, or communication. By modulating the carrier with audio tones and separating the tones at the receiving end of the circuit with suitable filters, it is possible to maintain two or more functions simultaneously over a single carrier channel. There are several advantages of such a system: the effective selectivity of the receiver is increased, permitting more functions in one channel, and the effect of noise on the transmission line is reduced.

Figure 1 shows how the effective selectivity of the receiver is increased. If no tones were used, just one function could be transmitted over the carrier channel. On the basis of a total band width of only 1,650 cycles, the received side frequency furthest removed from the carrier would be 825 cycles. If tones are to be received, but no voice communication, it would be practical to use frequencies of 150, 209, 290, 403, 560, and 778 cycles per second, which amounts to 38 per cent separation between tones. With such a separation, audio filters of sufficient selectivity to pass one tone and reject all others can be designed readily. If one tone per function is allowed, this provides for six functions in a single carrier channel where only one was available without tones. Thus the effective selectivity of the receiver has been increased six times.

In addition, it is better to obtain extreme selectivity with audio filters rather than with highly selective carrier-frequency circuits. When the figures in the preceding paragraph are used with six-tone pass bands and six corresponding no-pass bands between zero and 825 cycles, a 778-cycle tone filter can have a pass band approximately 90 cycles wide. Then the 778-cycle oscillator may have a drift of ±45 cycles or ± six per cent and still remain within the filter pass band. However, to maintain the same effective selectivity with carrier-frequency circuits, the frequency drift could not exceed ±0.045 per cent (±45 cycles at 100 kilocycles). Therefore, the stability of the carrier circuits need not be as great when tones are used as would be required to obtain the same effective selectivity with unmodulated carrier.

Noise on a power transmission line covers a wide frequency range, but the selective circuits of the receiver permit the reception of only the noise components in the channel to which it is tuned. When no tones are used, it is advantageous to adjust the receiver to accept only a narrow band of frequencies, as the line

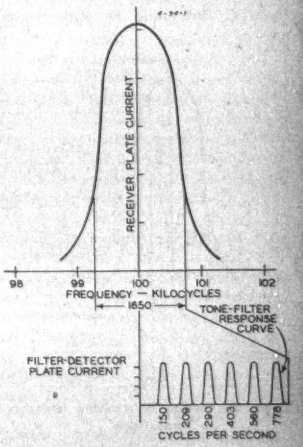

Figure 1. Typical receiver and tone-filter response curves

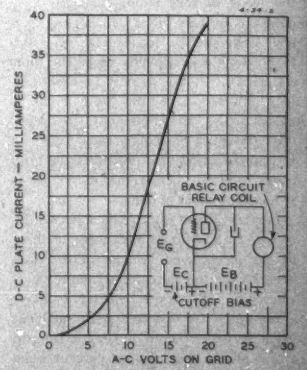

Figure 2. Dynamic characteristic of a biased detector

Paper 44-34, recommended by the AIEE joint subcommittee on power-system applications of carrier current for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted November 12, 1943; made available for printing December 6, 1943.

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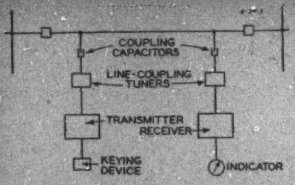

Figure 3. Simple carrier telemetering

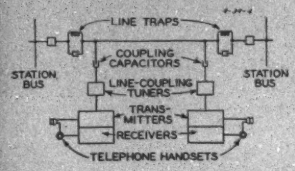

Figure 4. Basic carrier for pilot relaying

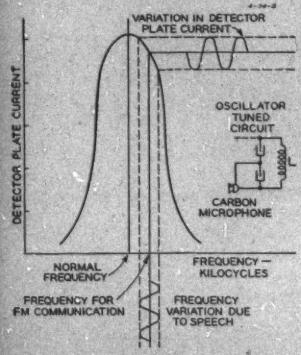

Figure 5. Method of receiving frequency modulation

noise received is proportional to the receiver band width. If the receiver output feeds six tone filters, then the noise accepted by each filter will be less than one sixth of the total noise received. How much less depends upon the filter selectivity. If the spacing between any two adjacent tone-filter pass bands is equal to the pass-band width in cycles, then the noise passed by each filter will be approximately one twelfth of the total noise received. Thus the use of tones reduces the effect of noise.

Further, if the filter feeds a biased detector, an additional advantage of three to one is obtained because of the nonlinearity of the detector dynamic characteristic. A biased detector employs a vacuum tube operated with sufficient negative bias voltage on its control grid to cut off the flow of plate current when no signal is being received. When an a-c voltage is applied to the grid, plate

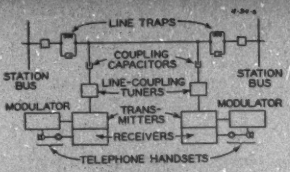

Figure 6. Carrier relaying plus modulator for communication

current flows on the positive half cycles. A plot of d-c plate current versus a-c grid voltage under operating conditions is known as the dynamic characteristic of the tube circuit. A typical curve is given in Figure 2. Reference to the curve shows that if a noise level of five volts is applied to the detector grid, the tube plate current is two milliamperes; if the noise plus signal is ten volts, the plate current is ten milliamperes. A relay adjusted to operate at six or eight milliamperes will not be operated by a noise voltage of five volts, yet reliable operation will be obtained on a total noise plus signal voltage of ten. This is a major advantage of tone-modulated carrier as it allows satisfactory reception of a signal through noise of approximately the same magnitude.

Expansion of a Carrier System

The following paragraphs trace the expansion of a power-line-carrier system from the simplest single-purpose arrangement to a complex installation which will provide several functions simultaneously in addition to carrier relaying. Figure 3 shows the simplest arrangement which will provide for telemetering a single quantity over a carrier channel. At the sending end, a transmitter is coupled through a line-tuning unit and coupling capacitor to the power line. In one system, the transmitter is turned on and off, or "keyed," by the telemetering device at a rate governed by the quantity being measured. In another system, the impulse rate remains constant, but the duration of the impulse varies. The carrier-frequency impulses so produced travel along the transmission line to the receiving end which employs similar coupling and tuning equipment, and, in addition, a receiver tuned to the transmitted frequency. The received impulses indirectly energize an indicating or recording instrument, giving a reading proportional to the quantity being measured at the transmitting end.

Line traps are generally unnecessary when carrier relaying is not included but may be used if the line loss between stations and the number of paths over which the carrier energy can divide are too great. Traps may also be used if different conditions of line switching cause wide variations in carrier loss between stations. However, this will not always eliminate signal variation as an appreciable fraction of the total carrier energy can flow in the untrapped phases of the transmission line. This energy goes on into other line sections and may cause increased loss because of reflection or absorption. Three-phase trapping will eliminate such a condition, but the selection of a different carrier frequency usually obviates the necessity of inserting traps in all three phases. Energy absorbed by a parallel line is also a potential cause of increased loss, but this, too, can be minimized by changing the frequency.

Figure 4 illustrates the basic carrier elements required for pilot relaying. The carrier signal for relaying is used to prevent the protective relays from tripping the breakers in a given line section for a fault external to that section. Carrier is transmitted from the station where fault power leaves the line section and blocks the relays at the station where the fault power enters the line section. Consequently, a transmitter, receiver, and suitable line-tuning and coupling equipment are located at each end of the line section to provide correct operation for external faults in either direction. Line traps are located between the coupling capacitor and the station bus in the phase wire to which carrier is coupled. From a relaying standpoint, the main function of a line trap is to prevent short-circuiting the carrier signal upon the occurrence of a ground fault just external to the line section on the phase wire to which carrier is coupled. Without the trap, such a fault might short-circuit the carrier signal and cause incorrect relay operation.

Supervisory control or telemetering of a single quantity in either direction can be provided in addition to relaying by keying the transmitter as before. The keying device for the added function is placed in parallel with the relay contacts which start carrier by closing the cathode circuit of the tubes in the transmitter. When high-rate telemetering is used, it is desirable to insert between the keying device and the carrier transmitter an electronic link which reduces to a fraction of a milliampere the current the telemetering contact is required to make and break in controlling carrier. Longer contact life and less maintenance

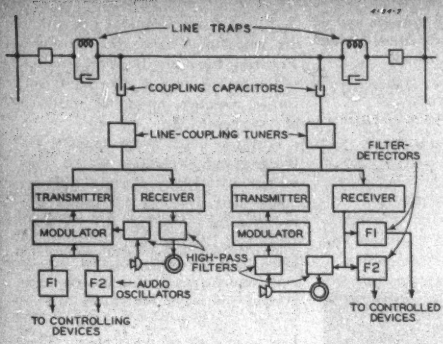

Figure 7. Audio tones added to carrier relaying

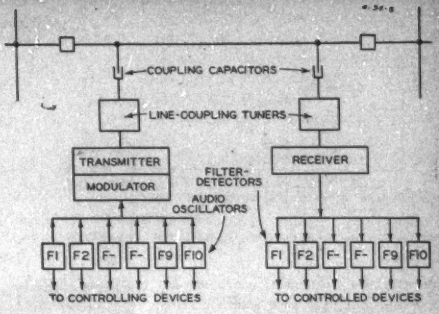

Figure 8. Use of tones to provide up to ten remotely controlled functions

are the advantages of such an electronic link.

Emergency voice communication between the carrier equipments can be effected by connecting the handset microphone across a low impedance section of the oscillator tuned circuit. Variation in the microphone resistance due to speech results in frequency modulation of the transmitted carrier. To receive frequency modulation, the carrier receiver must be capable of producing an output voltage or current proportional to the instantaneous change in frequency of the transmitter. A normal relaying signal receiver can be used satisfactorily for this application for the following reasons: When the microphone is connected into the oscillator tuned circuit, the resonant frequency of the circuit is changed by a small percentage. The receiver, which is normally tuned exactly to the transmitter frequency, is now slightly off resonance, as indicated in Figure 5, and is operating on the sloping portion of its resonance curve. When the transmitted frequency shifts back and forth because of speech, the detector plate current varies accordingly, and an audible signal is produced in the handset receiver.

This is probably one of the oldest forms of modulation, but it is still applicable, as it provides intelligible communication with a minimum of additional parts.

If communication between stations is desired from the switchboard panel, a modulator may be added to amplitude-modulate the carrier signal. Figure 6 illustrates an assembly which provides for carrier relaying and "push-to-talk" voice communication over a line section. It can be used also for telemetering a single quantity. The systems diagrammed in Figures 4 and 6 can be used for only one function at a time. If telemetering is used, it must be suspended in order to talk over the carrier channel, and, of course, during a fault, the protective relays take precedence over all other functions in controlling carrier.

When it is desired to have several functions on a single carrier channel simultaneously audio tones can be used to advantage. For example, consider an installation of carrier relaying where voice communication and telemetering of two quantities are desired. In order to transmit two quantities without interference, the measuring device associated with each controls a separate audio tone oscillator which amplitude-modulates the carrier signal. At the receiving end, the modulated carrier is fed into a detector tube to separate the audio from the carrier. The audio is then fed into filter circuits, each of which is tuned to pass one of the tone frequencies. The output voltage of each filter is applied to the grid of a vacuum tube operated as a biased detector, the operation of which was previously explained. An auxiliary relay in the plate circuit of the "filter-detector" controls the telemetering indicating device. Figure 7 illustrates such a system which can be used for telemetering two quantities as explained heretofore, for load control, or for remote tripping. For load control, the two audio tones provide raise and lower impulses to the governor of a generator; for remote tripping, the contacts of the two filter-detector auxiliary relays are connected in series to energize the breaker trip coil. To initiate a remote-tripping operation, both audio tones are transmitted (started either manually or by protective relays), and both filter-detectors at the receiving end are energized, thus completing the breaker trip circuit. The purpose of using two tones in this manner is to reduce the possibility of an incorrect breaker operation because of line noise or other disturbance producing a momentary signal which contains one of the tone frequencies.

If voice communication is included, a precaution must be taken to eliminate from the transmitter the voice frequencies which are identical with the tone frequencies. This is necessary to prevent speech from energizing the filter detectors at the receiving terminal and can be accomplished by inserting between the microphone and the modulator a filter which eliminates the tone frequencies from the speech input. By selecting tone frequencies below 500 cycles, several tones may be used simultaneously with communication. The speech filter can be of the high-pass type to attenuate all frequencies below 500 cycles 40 to 50 decibels so there is no danger of their energizing a filter detector. The elimination of these frequencies does very little to impair the intelligibility of speech.

In those cases where the tones are transmitted infrequently, as for remote tripping, the high-pass filters are not necessary in the telephone receiver circuit because the interference with speech reception is of short duration. However, for telemetering and other functions requiring the tones to be impulsed continuously, filters should be provided in the telephone receiver circuit. The aforementioned features are indicated in Figure 7.

Figure 8 illustrates extensive use of tones without communication or relaying and will provide up to ten remotely controlled functions over a single carrier channel. As all ten tones may be transmitted simultaneously, each tone must be adjusted to modulate the carrier signal not more than ten per cent to prevent overmodulation. This would cause severe distortion and generation of

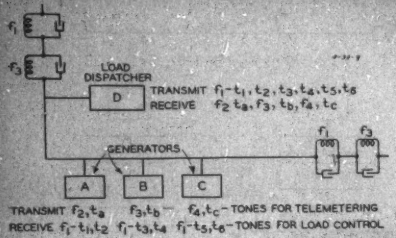
LOAD DISPATCHER
D
TRANSMIT f_1-$t_1, t_2, t_3, t_4, t_5, t_6$
RECEIVE f_2 t_a, f_3, t_b, f_4, t_c
GENERATORS
A
B
C
TRANSMIT f_2, t_a f_3, t_b f_4, t_c – TONES FOR TELEMETERING
RECEIVE f_1-t_1, t_2 f_1-t_3, t_4 f_1-t_5, t_6 – TONES FOR LOAD CONTROL

Figure 9. Extensive use of tones for telemetering and load control

$f_2 = (N - 1.5)$ kilocycles
$f_3 = (N)$ kilocycles
$f_4 = (N + 1.5)$ kilocycles

spurious side frequencies which are undesirable and may give interference in adjacent channels.

Since the percentage modulation per tone must be decreased when the number of tones is increased, the carrier sideband power in each tone is also decreased. Therefore, a more sensitive receiver is required for this application than for one where unmodulated carrier is received (assuming the same carrier power in both cases). Also, the receiver must have a low distortion characteristic so as to reproduce the tone frequencies without introducing unwanted harmonics. Ten audio tones can be spaced in a band from 150 to 3,000 cycles with a 38 per cent frequency separation between consecutive tones. To receive a carrier signal modulated with tones up to 3,000 cycles, the receiver must be capable of receiving a frequency band six kilocycles wide, and rejecting those outside the six-kilocycle band which may belong to another carrier channel. A simple receiver such as that used for relaying is not suitable for this application of tones. However, a broad-band superheterodyne receiver fulfills the preceding requirements of sensitivity, selectivity, and band width. Such a receiver should be equipped with automatic volume control to deliver sufficient audio voltage to the tone filters over a wide range of carrier input signal to allow for varying system conditions. For applications on lines with a high carrier loss, a receiver sensitivity great enough to provide dependable operation through a loss of 70 decibels is desirable.

A specific application of extensive use of tones for telemetering and load control is shown in Figure 9. The problem here is to keep the total load divided properly among three generators A, B, and C, and use as few carrier channels as practical. The load on each generator is to be telemetered to the load dispatcher at D, where load-control equipment sends raise and lower impulses back to the generating stations to keep the load divided as desired. These functions are accomplished thus: The carrier transmitters at stations A, B, and C are set at frequencies 1.5 kilocycles apart, and each is modulated with a different tone frequency for telemetering its generator load back to station D. The receiver at D is adjusted to receive a band wide enough to include the frequencies sent from A, B, and C, and the carrier side frequencies produced by the tones. Filters on the receiver at D separate the audio tones t_a, t_b, and t_c. The impulses provided by these tones operate the load-control equipment. Six audio tones are used to transmit the raise and lower load-control impulses from D to the generating stations A, B, and C on a single carrier frequency f_1 which may be widely different from f_2, f_3, and f_4. At each generating station, a receiver is tuned to f_1, and two tone filters pass the raise an lower impulses for that station. Only two carrier channels are needed; one channel 4.5 kilocycles wide to transmit f_2, f_3, and f_4, and another for f_1 with its six modulating audio tones. Double-frequency traps may be put in each end of the line if needed to allow satisfactory carrier reception under all conditions of system switching.

It will be noted in this example that the frequency separation of the transmitters at stations A, B, and C will cause major heterodynes of 1.5 and 3 kilocycles in the receiver at D. The audio tones t_a, t_b, and t_c must be sufficiently lower than 1.5 kilocycles that, for the maximum frequency drift of the transmitters, the major beat notes will still be far enough above the highest audio tone to produce no interference. There will be several minor heterodynes in the filter frequency band but of such low amplitude as to cause negligible interference.

Figure 10. Typical power-line-carrier assembly for relaying, remote tripping, and point-to-point communication

The Equipment

From the preceding examples of the use of power-line carrier, it is evident that the equipment must be of flexible electrical and mechanical design to be readily adaptable to widely varying applications. Rack-and-panel construction provides flexibility, and each major piece of equipment is constructed as a separate unit on standard 19-inch-wide relay rack panels. All external connections are brought out to terminal strips on the rear of each unit to facilitate interconnections between units and still maintain a pleasing appearance.

Figure 10 illustrates a typical installation which combines pilot relaying, two tone functions, and point-to-point communication. The entire rack assembly can be swung out of the cabinet on hinges to facilitate inspection and provide accessibility to all components.

Conclusions

1. Audio tones provide an effective way of increasing the usefulness of a carrier channel.
2. Simultaneous operation of several auxiliary functions over a single carrier channel can be provided without interference by using a separate tone for each function.
3. Satisfactory carrier transmission through a higher noise level can be realized by using tone modulation.
4. Telephone communication can be used simultaneously with tone-operated functions by using suitable filters to separate the tone and voice frequencies.

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1. Possibilities and Methods of Extending a Carrier-Current-Relay Channel to Other

Some Aspects of Inductance When Iron Is Present

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Synopsis: It is the purpose of this paper to examine various definitions of inductance based on the application in which the term is used. Comparisons are made between the definitions as a function of magnetomotive force and flux density for the special case of dynamo-grade (2.75 per cent) silicon steel. The effects of hysteresis and eddy currents are discussed. Consideration is confined to iron magnetic circuits in which no air gap exists, so that practical applications of conclusions drawn are limited somewhat.

THE usual definition of inductance is based on the assumption that the saturation curve is a straight line. Other assumptions, which are implied though not necessarily expressed, are that there is no residual flux, no hysteresis, and no eddy-current loss. For these conditions all definitions yield the same value of a constant inductance.

There are, however, many applications where solid iron is used in the magnetic structure. In the majority of these applications it is economically necessary to run the iron at a density which makes the saturation curve depart considerably from that of a straight line. Under these practical conditions eddy currents, hysteresis, and saturation all contribute to make a definition which assumes that constant inductance often be considerably in error.

The importance of this subject will be appreciated when it is recognized that the actual duty on the contact tips of a d-c contactor may be several times greater than would be expected from calculated values of the load inductance.

Use of the Term "Inductance"

The term "inductance" is used in connection with many circuits and phenomena. Its use in electric machinery often has been defined and elaborated on. There are, however, many instances, particularly in the industrial-control field, where a word is required to express a certain characteristic of a circuit, and that omnipresent word is "inductance." The following examples may be cited:

1. The build-up of current in the shunt field of a d-c machine, d-c contactor, relay, or brake is stated to depend on the time constant or ratio of inductance to resistance of the circuit.

2. The number of operations of which a contactor is capable depends to a great extent on the stored energy in the electric load which it is handling. In the case of a d-c contactor a large amount of this stored energy must be dissipated in the arc with consequent burning of tips, arcing horns, and chutes. The energy stored is stated to be one half of the product of inductance times current squared.

3. The rate of decay of d-c fields often is important when a field must be reduced rapidly or "killed." Here again decay is dependent supposedly on the time constant of the circuit.

4. When a contactor closes the tendency for the tips to weld or freeze depends on the rate at which the current builds up, and this usually is considered to be inversely proportional to the inductance of the circuit.

5. When a contactor interrupts an a-c circuit, the recovery voltage, after a current zero, rises at a rate which is dependent on the circuit inductance and capacitance.

6. In obtaining the inductance of an iron-core reactor it is common practice to read volts, amperes, and watts and to calculate the reactance and inductance from the data so obtained.

It will be shown in the following that for an iron-cored circuit the various inductances enumerated previously may be considerably different from each other, so much so that large errors result if they are used interchangeably.

Common Definitions of Inductance

There are three definitions of L commonly used in the literature.[1] The first is in terms of flux linkages per ampere, that is

$$L = \frac{\Psi_0}{i} = \frac{N\Phi_0}{i} \qquad (1)$$

In order that L be constant in equation 1, the condition must hold that flux is proportional to current. The second usual definition is to define L in terms of the back electromotive force by means of the equation

$$e = -L\frac{di}{dt} \qquad (2)$$

The third definition is in terms of the energy stored in a magnetic field and is given by the equations

$$W = -\int ei\,dt = \int_0^i Li\,di = \frac{1}{2}Li^2 \qquad (3)$$

Equations 1, 2, and 3 are used as the three basic definitions and give identical and constant values of L for the linear magnetization curve.

Although practically all textbooks and handbooks define inductance in one of these three ways, the majority (including the "American Standard Definitions of Electrical Terms" by AIEE) prefer to consider equation 2 as being basic.[2-5]

Equation 2 also may be stated

$$L = -\frac{e}{\frac{di}{dt}} = -e\frac{dt}{di} = N\frac{d\Phi_0}{di} \qquad (4)$$

and L is defined in this way by several other authors.[6,7]

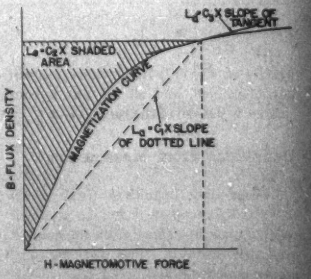
$L_d C_2$ X SLOPE OF TANGENT
$L_d = C_2$ X SHADED AREA
MAGNETIZATION CURVE
$L_0 = C_1$ X SLOPE OF DOTTED LINE
B-FLUX DENSITY
H-MAGNETOMOTIVE FORCE

Figure 1. Geometrical interpretation of L_0, L_d, and L_i in terms of the d-c magnetization curve

Paper 44-43, recommended by the AIEE committee on basic sciences for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted November 10, 1943; made available for printing December 13, 1943.

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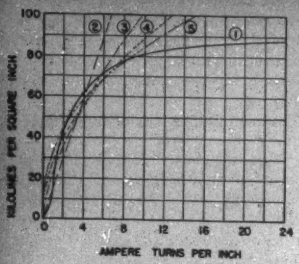


Figure 2. Comparison of the curves $H=KB^n$ with the magnetization curve of silicon steel

1. An actual curve for 2.75 per cent silicon steel
2. $H=(6.7)(10^{-2})B^8$
3. $H=(9.65)(10^{-3})B^{11}$
4. $H=(1.26)(10^{-3})B^9$
5. $H=(1.5)(10^{-4})B^{12}$

The "Standard Handbook for Electrical Engineers" edited by Knowlton lists both equations 2 and 3 as fundamental, calling L the coefficient of proportionality in each case.[8]

Equation 1 seems to be considered fundamental mainly by men concerned with the analysis of rotating machinery.[9–11]

Some textbooks redefine their fundamental magnetic concepts entirely when they change from air-core to iron-core circuits.[12] One author[13] expresses the opinion that L should not be introduced at all when the permeance of the circuit is variable.

Geometric Definition of Inductance

Another usual method of defining inductance[10] is to express it as a function of the physical dimensions. These include the area, length, and permeability of the flux paths, and dimensions and turns in the coils. This leads to the expression

$$L=(\text{constant})\left(N^2\frac{\mu A}{l}\right) \tag{5}$$

which is useful only if the value of μ can be determined, and all the flux is considered to link all of the turns.

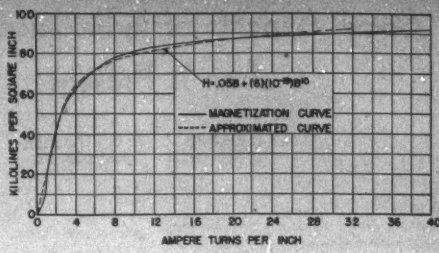
Definitions From Measurements

Besides these definitions (from which it is hard to evaluate L for the practical case), L may be defined from the method used to measure it. Two methods commonly used are

1. A-c measurements

$$E=I(R+jX_L)=I(R^2+\omega^2L^2)^{1/2} \tag{6}$$

Figure 3. Comparison of the d-c magnetization curve for 2.75 per cent silicon steel with the equation $H=0.05B+(6)(10^{-19})B^{10}$



So

$$L=\frac{1}{\omega}\left(\frac{E^2}{I^2}-R^2\right)^{1/2} \tag{7}$$

or if

$$R\ll\omega L$$

$$L=\frac{1}{\omega}\frac{E}{I} \tag{8}$$

2. Oscillogram of current change

$$E=iR+L\frac{di}{dt}\quad\text{for an } R\text{–}L \text{ series circuit} \tag{9}$$

So

$$i=\frac{E}{R}\left(1-e^{-\frac{R}{L}t}\right)\quad\text{for current rise} \tag{10}$$

and

$$i=I_o e^{-\frac{R}{L}t}\quad\text{for current decay if } L \text{ is constant} \tag{11}$$

From these equations

$$L=\frac{Rt}{\log_e\frac{I_f}{I_f-i}}\quad\text{for build-up} \tag{12}$$

and

$$L=\frac{Rt}{\log_e\frac{I_o}{i}}\quad\text{for decay} \tag{13}$$

Summary of Definitions

In order to differentiate between the quantities denoted by the common term "inductance" in the inductances taken from the preceding definitions, the following subscripts and names have been given arbitrarily to L:

L_a = apparent inductance $=\Psi_o/i$ from equation 1

L_d = differential inductance $=\dfrac{-e}{(di/dt)}$

$=N\dfrac{d\Phi_o}{di}$ from equations 2 and 4

L_e = inductance based on energy $=\dfrac{2W}{i^2}$ from equation 3

L_g = inductance based on geometry

$=(\text{constant})\left(N^2\dfrac{\mu A}{l}\right)$ from equation 5

L_{ac} = inductance based on rms readings

$=\dfrac{1}{\omega}\dfrac{E}{I}$ from equation 8

L_{tb} = inductance based on time for current build-up $=\dfrac{Rt}{\log_e\frac{I_f}{I_f-i}}$ from equation 12

L_{td} = inductance based on time for current decay $=\dfrac{Rt}{\log_e\frac{I_o}{i}}$ from equation 13

Graphical Interpretation (Figure 1)

Figure 1 shows a magnetization curve plotted as B versus H. Since for a given magnetic circuit B is proportional to Ψ_0 and H to i, then

$$L_a=\frac{\Psi_o}{i}=(\text{constant})\left(\frac{B}{H}\right)$$

so that L_a is proportional to the slope of the straight line drawn from the point of

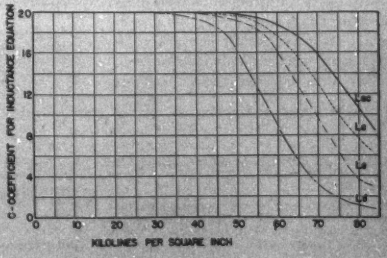


Figure 4. Variation of different inductances as a function of flux density

operation to the origin. This definition of L_a is very similar to the usual definition of μ which is defined as the ratio of B at a point to the H at that point.

Similarly

$$L_d = N\frac{d\Phi_2}{di} = (\text{constant})\left(\frac{dB}{dH}\right)$$

is proportional to the slope of the magnetization curve itself at a point and is analogous to μ_d, the differential permeability.

Also, since

$$W = -\int ei\,dt = \int i\frac{d\Psi}{dt}\,dt = \int i\,d\Psi$$

$$= (\text{constant})\int H\,dB$$

the energy stored in the magnetic field varies directly as the area between the magnetization curve and the vertical axis. Then L_a is proportional to this area for any given current.

Analytical Equivalent of a Magnetization Curve

An accurate analytical expression for the saturation curve is quite unwieldy, if it is desired to express B as a function of H. In order to approach a comparison of the different definitions of L mathematically, four flux versus current curves, namely $H = KB^n$ where $n = 1$, 1.5, 2, and 2.5 were assumed. These are shown in Figure 2 compared with the magnetization curve for 2.75 per cent silicon steel. A reactor was assumed to consist of N turns on a closed core of length l and cross-sectional area A. Resistance, leakage, and hysteresis were neglected. The inductance was calculated as a function of the current for L_a, L_d, and L_q, and as a function of rms current and rms voltage for L_{ac} for each of the assumed B–H curves. See Appendixes II, III, IV, and V.

Results are shown in Table I. It should be noted that for L_a, L_d, L_q, and L_{ac} as a function of current, the expressions vary only in their numerical coefficient. L_a is the greatest, and L_d is the least. It is also interesting to note that, if L_{ac} is written in terms of voltage, L_{ac} becomes a function of frequency—a rather surprising result.

A more accurate approximation to the saturation curve is given by $H = K_1B + K_2B^{10}$ which is shown in Figure 3. Because of the difficulty involved in solving this equation for dB/dH or for B as a function of H, the inductances are compared in terms of B and B_{rms} (Table I). These equations are shown plotted against B in Figure 4 and against H in Figure 5. The coefficient C is the value by which the expression $(N^2A/l)10^{-8}$ must be multiplied in order to obtain L in henrys. See Appendix II*B*.

For the case $H = K_1B + K_2B^{10}$ there does not seem to be a definite relationship between the different inductances, except that they all decrease quite rapidly as soon as the knee of the B–H curve is reached. Differential L drops the fastest and to the lowest value.

An air gap in the magnetic circuit would increase K_1 in the foregoing equation. Its effect would be to lower the C–H curves and to shift them to the right. All values of inductance would be lowered except L_d which at certain currents may be higher with an air gap in the circuit than when the core is closed.

Inductance When Hysteresis Is Present

Figure 6 shows the variation of L_d and L_q with current, that is, with H, as a hysteresis loop for Nicaloi steel is traced. It should be noted that the coefficient C in the equation

$$L_d = C\frac{N^2A}{l}\,10^{-8} \qquad (14)$$

varies from 4 to 175 over every half-cycle.

For L_q, C varies from minus to plus infinity which is a rather startling range for a quantity which is usually assumed constant. Figure 9 was drawn for Nicaloi, because it is a material which has a very low hysteresis-loop area and, therefore, is a close practical approach to a commercial material with no hysteresis. It is used extensively in transformers, reactors, and relays.

Figure 7 shows the same curves of L_a and L_d for a 2.75 per cent silicon steel. Here C in L_d varies from 0.8 to 4.7, and C in L_a, as before, goes from minus infinity to plus infinity.

Presence of Eddy Currents

Many oscillograms, taken on solid iron contactors and brakes to get current–time curves when a constant d-c voltage is applied, show a rapid initial rate of rise

Table I. Calculated Formulas of Inductance for Various Assumed Magnetization Curves

	$L_a = \frac{\Psi}{i}$	$L_d = \frac{d\Psi}{di}$	$L_q = \frac{2w}{i^2}$	$L_{ac} = -\frac{1}{\omega}\frac{E_{rms}}{I_{rms}}$	
$H = f(B_a)$	In Terms of Current i			In Terms of Rms Current	In Terms of Rms Voltage
$H = KB_a^{1.0}$	$1.0\frac{N^2A}{Kl}$	$1.0\frac{N^2A}{Kl}$	$1.0\frac{N^2A}{Kl}$	$1.0\frac{N^2A}{Kl}$	$1.0\frac{N^2A}{Kl}$
$H = KB_a^{1.5}$	$1.0\frac{N^{4/3}A}{K^{1/3}l^{2/3}I^{2/3}}$	$0.67\frac{N^{4/3}A}{K^{1/3}l^{2/3}I^{2/3}}$	$0.80\frac{N^{4/3}A}{K^{1/3}l^{2/3}I^{2/3}}$	$0.94\frac{N^{4/3}A}{K^{1/3}l^{1/3}I^{1/3}}$	$0.92\frac{N^{4/3}A^{2/3}\omega^{2/3}}{KlE^{1/3}}$
$H = KB_a^{2.0}$	$1.0\frac{N^{3/2}A}{K^{1/2}l^{1/2}I^{1/2}}$	$0.50\frac{N^{3/2}A}{K^{1/2}l^{1/2}I^{1/2}}$	$0.67\frac{N^{3/2}A}{K^{1/2}l^{1/2}I^{1/2}}$	$0.91\frac{N^{3/2}A}{K^{1/2}l^{1/2}I^{1/2}}$	$0.82\frac{N^2A^2\omega}{KlE}$
$H = KB_a^{2.5}$	$1.0\frac{N^{5/3}A}{K^{1/3}l^{2/3}I^{2/3}}$	$0.40\frac{N^{5/3}A}{K^{1/3}l^{2/3}I^{2/3}}$	$0.57\frac{N^{5/3}A}{K^{1/3}l^{2/3}I^{2/3}}$	$0.88\frac{N^{5/3}A}{K^{1/3}l^{1/3}I^{2/3}}$	$0.73\frac{N^{5/3}A^{2/3}\omega^{2/3}}{KlE^{2/3}}$
	In Terms of $B_{instantaneous}$			In Terms of B_m	
$H = K_1B + K_2B^{10}$	$\left(\frac{N^2A}{K_1l}\right)\frac{10^{-8}}{1+\frac{K_2}{K_1}B^9}$	$\left(\frac{N^2A}{K_1l}\right)\frac{10^{-8}}{1+10\frac{K_2}{K_1}B^9}$	$\left(\frac{N^2A}{K_1l}\right)\frac{\left(1+0.18\frac{K_2}{K_1}B^9\right)10^{-8}}{1+2\frac{K_2}{K_1}B^9+\left(\frac{K_2}{K_1}\right)^2B^{18}}$	$\left(\frac{N^2A}{K_1l}\right)10^{-8}\left[1+0.94\frac{K_2}{K_1}B_m{}^9+0.35\left(\frac{K_2}{K_1}\right)^2B_m{}^{18}\right]^{-1/2}$	

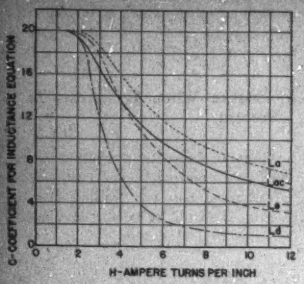


Figure 5. Variation of different inductances as a function of magnetomotive force

of current. This effect is attributed sometimes to remanent flux in the device and sometimes to eddy currents. Figure 8 is a copy of a typical oscillogram taken on a contactor having a magnetic circuit about 11 inches in length and average cross section of one square inch with a 0.015-inch air gap in the circuit. Tests taken of current build-up with both positive and negative remanent flux left in the circuit by previous operations showed practically no change in initial rise.

The values of inductance at different currents calculated from the oscillogram in a step-by-step process using the equation

$$L_d = \frac{E - Ri}{\frac{di}{dt}} \qquad (15)$$

are shown in Figure 9.

Curves 1 and 2 of Figure 9 show the variation of L with current build-up and curve 3 with current decay (calculated from an oscillogram). It should be noted that curve 3 reads from right to left with respect to time. Although direct comparisons of curves 1 and 3 are impossible because of the hysteresis loop, it is still significant to notice the high inductance exhibited by curve 3 at zero current compared with the inductance shown by curve 1. This probably is due to the difference in the rate of current in the coil. In the former case the d-c arc was going out slowly, while in the latter case a sudden voltage inducing large eddy currents was applied.

Other data, not reproduced here, in which the current and flux rise in a series brake magnet were measured, have shown that the time required for the flux in the air gap to reach its final value is about ten times as long as the time required for the current to build up. This lag is attributable to the demagnetizing action of the eddy currents and, of course, affects the inductance.

Inductance Based on Build-up and Decay of Current

Figure 10 shows calculated curves for the increase of current with time when a constant voltage is applied to a 2.75 per cent silicon-steel-core reactor, and saturation is taken into account, but hysteresis and eddy currents are neglected. Four such curves for different applied voltages are plotted. These curves were obtained by a step-by-step integration of the equation

$$E = Ri + L_d \frac{di}{dt} \qquad (16)$$

where the equation $H = 0.05B + (6)(10^{-19}) \times B^{10}$ was used instead of the true

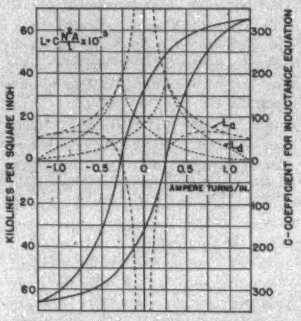


Figure 6. Variation of L_a and L_d over a complete cycle of the hysteresis loop of Nicaloi

B–H curve of the material. This was done, so that equivalent inductances (L_{eq}) calculated from the curves of Figure 10 could be compared with those obtained by calculation from other definitions. Equivalent inductance means that value of inductance which, if constant, would allow the current to reach the same percentage of its final value in the same time that it does in Figure 10. From these curves of Figure 10 the value of time at which the current was equal to 90 per cent of its final value was read. When equation 10 was used, the value of L_{eq}, the equivalent or constant inductance, was calculated. The same was done for current equal to 63 per cent of its final value. When these calculated values of L_{eq} were used, the curves 2 and 3 of Figure 12 were plotted. The difference between L_a, the usual definition for inductance for a d-c field, and the constant inductance, which should be used to give the true time of build-up, is shown clearly.

Curves 1 and 4 of Figure 12 are calculated from the decay curve of Figure 11. These current-decay curves were obtained in the same way the current-rise curves were found, that is, by a step-by-step integration of equation 16 when $E=0$ for the magnetization curve $H = 0.05B + (6)(10^{-19}) B^{10}$.

It should be noted that L_a in Figure 12 falls between curves 1 and 3 for the 90 per cent case and also between curves 2 and 4 for the 63 per cent case, that is, the apparent inductance is somewhere between the inductance calculated from build-up and decay.

If currents which are closer to 100 per cent of final are chosen, curve 3 will be lower and curve 1 will be higher, showing more and more error between apparent inductance and the constant inductance which gives the correct build-up or decay time.

Experimental Verification

An experimental verification of these theoretical curves is shown in Figure 13 which is a copy of an oscillogram. This was taken to measure the inductance of the field of a 50-horsepower synchronous motor, so that an equivalent circuit could be built in order to test the interrupting ability of switches of different ratings. From the slope of the current–time curve the inductance was computed by equation 14 and is shown plotted in Figure 14. It may be noted that the

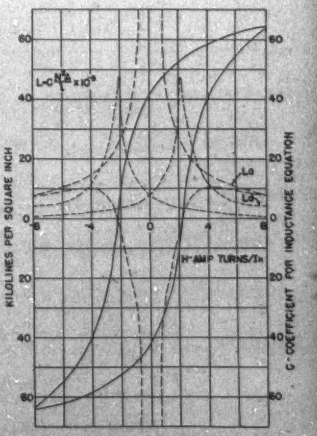


Figure 7. Variation of L_a and L_d over a complete cycle of the hysteresis loop of 2.75 per cent silicon steel

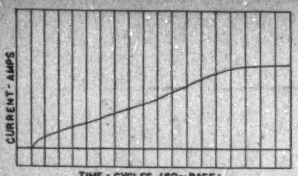


Figure 8. Traced copy of an oscillogram showing current build-up with constant applied voltage in a d-c solid-iron contactor with 0.015-inch air gap

current–time curve is very similar to those shown in Figure 10. The inductance of this machine had been given as 12 henrys; the oscillogram showed a range from nine to three henrys.

Conclusions

1. Although comparisons have been made in this paper between various definitions of L on the basis of a closed circuit and silicon steel, similar results can be obtained as readily for any other steel and circuit containing an air gap.

2. The assumption, that inductance is a constant in an iron magnetic circuit where the flux density is of the usual practical value, and the air gaps are small, leads to large errors. Saturation cannot be neglected merely to obtain a mathematical solution of a problem, for the solution then bears little relation to the actual case.

3. The true inductance of a circuit, in the sense of a back electromotive force, is the differential inductance. There is much work to be done to calculate differential inductance for magnetic circuits which have air gaps. Results probably can be expressed usefully in terms of mils of air gap per inch of iron. Such data on machines are necessary, if accurate control of those machines is to be precalculated.

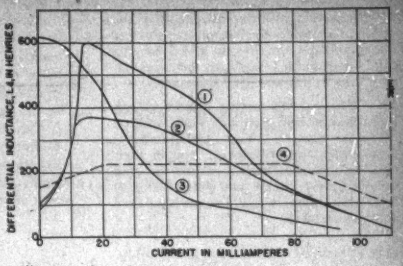
4. Observation of Figures 4, 6, and 12 shows the wide variations in inductance, depending on the method of calculation or measurement. The particular value to be used depends on the application to which it is applied.

5. The statement, that inductance is a function of the physical dimensions of a circuit and of μ, throws the whole definition into an evaluation of the value of μ and is for that reason of little use.

6. The widespread use of a time constant based on flux linkages per ampere, that is L_a, often leads to results considerably in error. With the great increase in speeds of voltage response called for on a large variety of industrial-control applications, such as variable-voltage planer drives or amplidyne-forced steel-mill motors, it is becoming increasingly necessary for the circuit designer to have more information regarding current build-up in the d-c fields. For accurate field control as a function of time, it is necessary to know an equivalent inductance (L_{eb}) which will give the correct build-up time.

Figure 9 (right). Variation of L_d with current for the d-c contactor of Figure 8

1. L_d calculated from current build-up after contactor had carried current in the negative direction. Air gap is 0.015 inch
2. L_d calculated from current build-up after contactor had carried current in the positive direction. Air gap is 0.015 inch
3. L_d calculated from an oscillogram of current decay. Air gap is 0.015 inch
4. Same as 1 but with an air gap of 0.375 inch



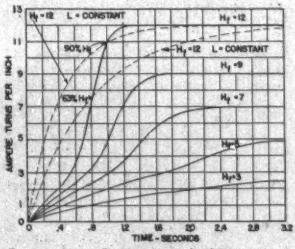


Figure 10. Current–time build-up curves calculated from $H=0.05B+(6)(10^{-19})B^{10}$ for various applied voltages compared with theoretical constant-inductance build-up curves

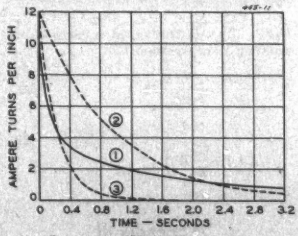


Figure 11. Current-decay curves

1. Current–time-decay curve for the material given by $H=0.05B+(6)(10^{-19})B^{10}$
2. H-versus-time curve for the constant inductance (L_{cb}) which crosses curve 1 at 10-per cent of its original value
3. H-versus-time curve for the constant inductance (L_{td}) which crosses curve 1 at 37 per cent of its original value

7. In specifying the interrupting ability of contactors which handle motor loads, it would seem advisable, in order to obtain comparative data, to set up L/R ratios for air-core reactors rather than to specify motor loads. Much work still remains to be done to identify the effect of a variable inductance load on both a-c and d-c interruption, so that equivalent air-core loads can be used for test purposes.

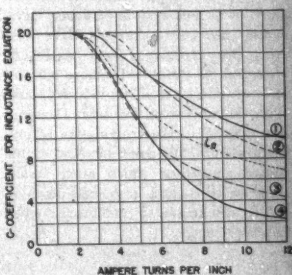


Figure 12. Variation of L_{td} and L_{tb} with magnetomotive force

1. L_{td} for decay time at which $i=10$ per cent I_o
2. L_{tb} for build-up time at which $i=63$ per cent I_f
3. L_{cb} for build-up time at which $i=90$ per cent I_f
4. L_{td} for decay time at which $i=37$ per cent I_o

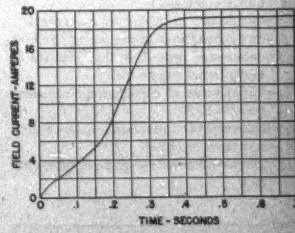


Figure 13. Traced copy of an oscillogram showing current build-up versus time at constant applied voltage for a 50-horsepower synchronous-motor field

8. In the majority of d-c circuits containing solid iron, eddy currents affect the initial rate of current rise, so that a calculated inductance, such as L_a, is not a dependable criterion for severity of the circuit with respect to tip welding. To obtain comparative data air-core inductances should be specified.

9. The authors have made no investigations as yet on a circuit which contains motor or reactor loads to find the inductance

which, together with the capacitance of the system, determines the natural frequency of the circuit and so critically affects a-c circuit interruption. Such an investigation may lead to still another inductance.

10. Electrical engineering courses in college could include profitably more work on magnetic circuits. Very few textbooks even admit the presence of iron in their treatment of the classical current rise and decay in a d-c circuit, and yet in industry few examples can be found where iron is not a dominant factor.

It is realized that the foregoing analysis is by no means complete, and that much work remains to be done. Hysteresis and eddy currents have been taken into account in some places and neglected in others. Leakage has not been considered at all. It is hoped, however, that this work will serve to stimulate interest in the examination of iron circuits from the point of view of the control apparatus which must handle those circuits and also will lead to AIEE definitions of inductance when iron is present.

Appendix I. Nomenclature

L = inductance in henrys
e = voltage at time t
i = instantaneous value of current
Ψ_ϕ = flux linkages—webers times turns
Ψ = flux linkages—kilolines times turns
t = time—seconds
W = energy—joules
I = rms current
E = rms voltage or d-c voltage
Φ_ϕ = flux in webers
Φ = flux in kilolines
B_ϕ = flux density in webers per square inch
B = flux density in kilolines per square inch
B_m = maximum value of flux density in kilolines per square inch
I_o = initial value of current for d-c current decay = E/R
I_f = final value of current build-up case = E/R
R = resistance in circuit
H = magnetizing force—ampere turns per inch
H_f = final value of magnetomotive force in a d-c circuit
l = length of the magnetic path in inches
A = cross section of the magnetic path in square inches
L_a, L_d, L_q, L_0, L_{aa}, L_{dd}, L_{dd} are defined in the text in the paragraph "Summary of Definitions"
$\omega = 2\pi f$ where f is the frequency
μ = permeability
A = area of an iron circuit in square inches

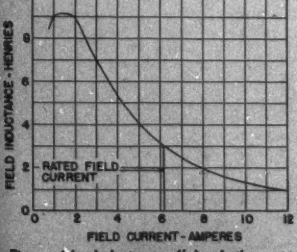


Figure 14. Inductance (L_d) of the synchronous-motor field calculated from Figure 13

Appendix II

A. Calculation of L_a when $H = KB_\phi^n$. From equation 1, which is the defining equation for L_a

$$L_a = \frac{N\Phi_\phi}{i} = \frac{NAB_\phi}{i} \tag{17}$$

Substituting $H = KB_\phi^n$ into equation 17 yields

$$L_a = \frac{NA}{i}\left(\frac{H}{K}\right)^{\frac{1}{n}} \tag{18}$$

and

$$H = \frac{Ni}{l} \tag{19}$$

so that

$$L_a = \frac{NA}{i}\left(\frac{Ni}{lK}\right)^{\frac{1}{n}} \tag{20}$$

Substitution of $n = 1.0$, 1.5, 2.0 and 2.5, into equation 20 gives the formulas for L_a shown in Table I.

B. Calculation of L_a when $H = K_1B + K_2B^{10}$. By substituting the value of i from equation 19 in equation 17

$$L_a = \frac{N^2AB_\phi}{lH} = \frac{N^2AB}{lH}\,10^{-8} \tag{21}$$

$$= \frac{N^2A\,10^{-8}}{lK_1\left(1+\frac{K_2}{K_1}B^9\right)} \tag{22}$$

Appendix III

A. Calculation of L_a when $H = KB_\phi^n$

$$W = \int ei\,dt \quad \text{and} \quad e = NA\frac{dB_\phi}{dt}$$

so that

$$W = NA\int i\,dB_\phi$$

Now

$$B_\phi = \left(\frac{H}{K}\right)^{\frac{1}{n}}$$

and

$$dB_\phi = \frac{1}{n}\frac{H^{\left[\frac{1}{n}-1\right]}}{K^{\frac{1}{n}}}\,dH \tag{23}$$

$$dB_\phi = \frac{1}{nK^{\frac{1}{n}}}\left(\frac{iN}{l}\right)^{\left[\frac{1}{n}-1\right]}dH \tag{24}$$

and

$$W = \frac{NA}{nK^{\frac{1}{n}}}\left(\frac{N}{l}\right)^{\frac{1}{n}}\int i^{\frac{1}{n}}di$$

$$= \frac{AN^{\left[1+\frac{1}{n}\right]}}{K^{\frac{1}{n}}l^{\frac{1}{n}}}\left(\frac{i^{\left[1+\frac{1}{n}\right]}}{n+1}\right) \tag{25}$$

Since

$$W = \frac{1}{2}Li^2$$

then

$$L = \frac{2W}{i^2} = \frac{2AN^{\left[1+\frac{1}{n}\right]}i^{\left[\frac{1}{n}-1\right]}}{K^{\frac{1}{n}}l^{\frac{1}{n}}(n+1)} \tag{26}$$

Substitution of $n = 1.0$, 1.5, 2.0, and 2.5 in equation 26 yields the formulas shown for L_a in Table I.

B. Calculation of L_a when $H = K_1B + K_2B^{10}$

$$W = \int ei\,dt = lA\int H dB_\phi$$

and

$$L = \frac{2W}{i^2} = \frac{2AN^2}{lH^2}\int H dB_\phi \tag{27}$$

$$= \frac{2AN^2 10^{-8}}{lH^2}\int (K_1B + K_2B^{10})dB$$

$$= \frac{AN^2 10^{-8}}{l}\,\frac{(K_1B^2 + 0.182K_2B^{11})}{K_1^2B^2 + 2K_1K_2B^{11} + K_2^2B^{20}}$$

$$= \frac{AN^2}{lK_1}\,\frac{\left(1+0.182\,\frac{K_2}{K_1}B^9\right)10^{-8}}{1+2\frac{K_2}{K_1}B^9+\left(\frac{K_2}{K_1}\right)^2B^{18}} \tag{28}$$

Appendix IV

A. Calculation of L_d when $H = KB_\phi^n$ From equation 4 which defines L_d

$$L_d = N\frac{d\Phi_\phi}{di} = NA\frac{dB_\phi}{di} \tag{29}$$

where

$$B_\phi = \left(\frac{H}{K}\right)^{\frac{1}{n}} = \left(\frac{Ni}{Kl}\right)^{\frac{1}{n}}$$

Then

$$\frac{dB_\phi}{di} = \frac{1}{n}\left(\frac{N}{Kl}\right)^{\frac{1}{n}} i^{\left[\frac{1}{n}-1\right]} \tag{30}$$

and

$$L_d = \frac{NA}{n}\left(\frac{N}{Kl}\right)^{\frac{1}{n}}\frac{1}{i^{\frac{n-1}{n}}} \tag{31}$$

which is equal to L_a/n. Substitution of $n = 1.0$, 1.5, 2.0, and 2.5 into equation 31 gives the formulas for L_d in Table I.

B. Calculation of L_d when $H=K_1B+K_2B^{10}$

$$L_d=\frac{Nd\Phi_0}{di}=\frac{N^2A}{l}\frac{dB_0}{dH}=\frac{N^2A}{l}\frac{dB}{dH}10^{-8} \quad (32)$$

$$=\frac{N^2A}{l}\frac{10^{-8}}{K_1+10K_2B^9}$$

$$=\frac{N^2A}{lK_1}\frac{10^{-8}}{\left(1+10\frac{K_2}{K_1}B^9\right)} \quad (33)$$

Appendix V

A. Calculation of L_{ac} when $H=K(B_0)^n$. Assuming no resistance or hysteresis

$$L_{ac}=\frac{1}{\omega}\frac{E}{I}=\frac{1}{\omega}\frac{E_m}{(2)^{1/2}\left[\frac{1}{T}\int_0^T i^2dt\right]^{1/2}} \quad (34)$$

Now

$$e=NA\frac{dB_0}{dt}=E_m\sin\omega t$$

when B_0 is in webers per square inch, so that

$$B_0=\frac{-E_m}{NA\omega}\cos\omega t \quad (35)$$

Now

$$i=\frac{lH}{N}=\frac{lKB_0^n}{N} \quad (36)$$

$$=\frac{lK}{N}\left(\frac{-E_m}{NA\omega}\cos\omega t\right)^n \quad (37)$$

When $n=1$, 1.5, 2, and 2.5 is substituted in equation 36, and equation 34 is evaluated, the results shown in Table I for L_{ac} in terms of E_m are obtained.

Substituting $\omega LI=E$ in the equations so derived yields the formulas shown for L_{ac} in terms of I in Table I.

B. Calculation of L_{ac} when $H=K_1B+K_2B^{10}$

$$L_{ac}=\frac{1}{\omega}\frac{E}{I}=\frac{NAB_m10^{-8}}{\sqrt{2}\,I}=\frac{0.707NAB_m10^{-8}}{I} \quad (38)$$

Now

$$I=\left(\frac{4}{T}\int_0^{\frac{T}{4}}i^2dt\right)^{\frac{1}{2}}=\frac{2l}{N}\left(f\int_0^{\frac{1}{4f}}H^2dt\right)^{1/2} \quad (39)$$

Substituting for H as a function of B we obtain

$$I=\frac{2l}{N}\left(f\int_0^{\frac{1}{4f}}(K_1{}^2B_m{}^2\cos^2\omega t+2K_1K_2B_m{}^{11}\times\cos^{11}\omega t+K_2{}^2B_m{}^{20}\cos^{20}\omega t)dt\right)^{1/2} \quad (40)$$

Evaluation of this expression (Hudson's manual equation 330)

$$I=\frac{0.707lK_1B_m}{N}\left[1+0.942\frac{K_2}{K_1}B_m{}^9+0.352\left(\frac{K_2}{K_1}\right)^2B_m{}^{18}\right]^{1/2} \quad (41)$$

$$L_{ac}=\frac{N^2A}{K_1l}(10^{-8})\left[1+0.942\frac{K_2}{K_1}B_m{}^9+0.352\left(\frac{K_2}{K_1}\right)^2B_m{}^{18}\right]^{-1/2} \quad (42)$$

By plotting equation 41 for I versus B_m and equation 42 for L_{ac} versus B_m, the plot of L_{ac} versus I is obtained, which is shown in Figure 5.

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A Magnetic-Type Air Circuit Breaker for 15,000-Volt Services

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Synopsis: In the development of the five-kilovolt Magne-Blast air circuit breaker, it was shown that rapidly increased arc resistance was extremely effective in circuit interruption. This paper describes an extension of that principle in the development of a Magne-Blast circuit breaker for 15-kv services with an interrupting rating of 250,000 kva. The higher electrical resistance of the arc necessary for this voltage has been made possible by an increase in the thermal efficiency of the interleaving arc chute. The arc chute which provides this greater efficiency is discussed in some detail. The design of the breaker is described briefly as well as its application to metal-clad switchgear. Test data and representative oscillograms are submitted to substantiate the interrupting rating assigned to this breaker.

MODERN switchgear equipments with moderate-voltage air circuit breakers have been used to considerable advantage during the recent period of industrial expansion. Under the severe service conditions of this greatly accelerated war program, magnetic-type air circuit breakers have proved their worth in reliable operation with a minimum of maintenance. The trend toward air circuit breakers for all moderate distribution voltages has been hastened by this experience, and demands for an extension of the line are real. The design history and performance characteristics of a development that eventually will extend the application of magnetic-type air circuit breakers to 15-kv service with interrupting capacities of 250,000 and 500,000 kva are presented here.

The first Magne-Blast air circuit breakers were introduced for 2,300-to 5,000-volt service. Intended to replace the conventional oil circuit breaker of comparable ratings, these breakers were designed as the removable switching unit of modern vertical-lift metal-clad switchgear. These breakers emphasized the beneficial effects of rapidly increasing the resistance of the arc prior to interruption of a-c circuits, both from the standpoint of current reduction and reduction of the rate of rise of recovery voltage. Heretofore, it had been considered generally that increasing arc resistance only increased the energy that had to be dissipated in the interrupter and was therefore to be avoided.

Since being described before the Institute in 1939,[1] additional sizes had been developed to include 50,000 to 150,000 kva at 5 kv and 250,000 kva at 7.5 kv. The operating record of the several thousand Magne-Blast breakers now in service has been so satisfactory that it was imperative to continue this development into the 15-kv range at 250,000 kva and higher. An extensive development program was therefore initiated to develop a 15,000-volt air circuit breaker. How it has been possible to extend the Magne-Blast principles of interruption in the development of such a 15,000-volt air circuit breaker having 250,000-kva interrupting capacity is described in the following sections. A brief description of the breaker and representative oscillograms also are presented.

Development of the 15-Kv Arc Chute

The primary problems in the development of an arc chute suitable for a 15-kv magnetic air circuit breaker are those of providing sufficient arc cooling to insure positive interruption and sufficiently high dielectric strength to withstand the insulation requirements of this voltage while still maintaining the approximate space requirements of the corresponding oil circuit breaker. The general form of the interleaving arc chute developed for the lower-voltage Magne-Blast breakers provided an interrupter that promised to interrupt considerable current at much higher voltages. This arc chute has parallel fins which project alternately from the two inner sidewalls. As the arc is forced magnetically into the arc chute, it meets fins of gradually increasing

Table I. 15,000-Volt 250,000-Kva Magne-Blast Circuit Breaker

Test Number	Test Voltage	Maximum-Phase Rms Amperes (Closing)	Maximum-Phase Rms Amperes (Initial in Arc Interrupted)	Arcing Time (Cycles)	Trip Impulse to Interruption	Three-Phase Kva Interrupted
Three-Phase Interrupting Tests—Opening Tests						
1–4	14,500		4.6	0.8	2.9	120
5–8	14,500		8	0.8	2.9	200
9–12	14,500		17	1.4	3.6	440
13–22	14,500		38	2.0	4.0	960
23–32	14,500		74	2.1	4.2	1,600
33–36	14,500		130	2.0	4.0	3,300
37–40	14,500		270	2.2	4.3	6,800
41–44	14,500		600	2.2	4.3	15,000
45–46	14,500		1,990	2.1	4.3	50,000
47	14,500		3,000	1.7	3.9	75,000
48	14,500		4,800	1.4	3.8	120,000
49	14,500		10,300	1.3	3.6	260,000
50	14,500		9,300	1.0	3.3	240,000
51	14,500		10,900	1.1	3.3	270,000*
52	10,000		9,700	1.1	3.4	170,000
53	11,000		12,200	0.9	3.2	230,000
54	11,000		15,100	0.9	3.2	290,000
55	14,500		2,200	1.8	4.1	55,000
56	14,500		5,500	1.3	3.6	140,000
57	14,500		10,500	1.0	3.3	260,000
58	14,500		1,710	1.9	4.2	43,000
59	14,500		11,400	1.0	3.1	290,000
Three-Phase Trip-Free Closing–Opening Tests						
60	14,500	2,500	1,670	1.0	4.3	42,000
61	14,500	2,200	1,780	1.8	4.1	45,000
62	14,500	7,700	5,900	1.4	3.4	150,000
63	14,500	12,600	9,200	1.2	3.2	230,000
Three-Phase Two-Operation Duty Cycle–15-Second Reclosing						
64a	14,500	12,600	10,300	1.5	3.8	260,000
b	14,500	16,600	12,200	1.2	3.5	310,000**
Three-Phase Interruption Tests–Opening Tests						
65	14,500		8,100	1.3	3.7	200,000
66	14,500		6,700	1.4	3.7	170,000
67	14,500		9,600	1.3	3.5	240,000
68	11,000		17,000	1.3	3.6	320,000
69	11,000		14,200	1.4	3.6	270,000
70	11,000		14,500	1.4	3.7	280,000
71	11,000		11,200	0.9	3.1	210,000

* See Figure 8. ** See Figure 9.

Paper 44-47, recommended by the AIEE committee on protective devices for presentation at the AIEE winter technical meeting, New York, N. Y., January 24-28, 1944. Manuscript submitted November 26, 1943; made available for printing December 13, 1943.

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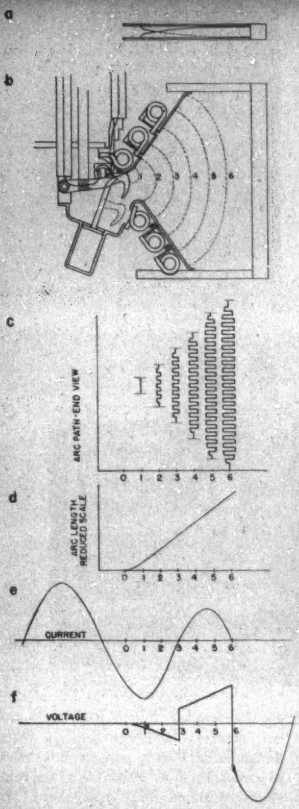


Figure 1. Schematic view of arc interruption in 15,000-volt Magne-Blast arc chute

(a). Plan view of arc chute showing gradual increase in depth of interleaving fins

(b). Successive positions of arc as it is forced into chute. Blowout coils are inserted one at a time as arc travels along arc runners

(c). Cross-section views of successive arc positions

(d). Progressive increase of length of arc—reduced scale

(e). Short-circuit current showing reduction effected by resistance of long arc prior to interruption

(f). Voltage across contacts of breaker which is zero with breaker closed. As contacts part and arc increases in length, its increasing resistance produces a rising arc-voltage drop. At current interruption voltage assumes 60-cycle line-voltage value

depth extending deeper and deeper into the matching slots between the fins of the opposite side. Where the fins interleave across each other, the arc is folded back and forth gradually into a serpentine path as it proceeds into the arc chute, where it is lengthened rapidly, and its resistance is increased greatly through the transfer of thermal energy to the arc-chute surfaces. The effect of the interleaving arc chute in increasing the length and resistance of the arc and the effect of this resistance in reducing the short circuit and instantaneous recovery voltage are shown schematically in Figure 1.

Experience gained in the development of 5,000- and 7,500-volt Magne-Blast breakers showed that the voltage which could be interrupted by an interleaving arc chute is proportional to

(*a*). The length of serpentine arc path.

(*b*). The thermal effectiveness of the interleaving fins in removing heat per unit length of arc.

(*c*). The strength of the transverse magnetic field available for forcing the arc into the chute.

(*d*). The spacing of the arc runners for sustaining recovery voltage.

(*a*). Both the length of the arc path and the thermal efficiency of the interleaving fins in the arc chute are effective in increasing the arc resistance prior to current zero. The short-circuit current is reduced by the introduction of this arc resistance into the circuit, the reduction often being as much as 25 to 30 per cent of current values prior to contact parting. The instantaneous recovery voltage is reduced likewise in magnitude, for the current zero is advanced from its normal lag of 90 degrees toward or beyond the normal voltage zero. For a given value of short-circuit current, this arc resistance must be increased directly with the applied voltage to obtain the same percentage current reduction and instantaneous recovery-voltage reduction.[2,3]

Item *a*, or the relationship between voltage-interrupting characteristics and the length of the serpentine arc path can be checked easily by tests. To do this two 7,500-volt arc chutes and their associated breaker parts were connected in series and opened simultaneously on a 15,000-volt connection in the testing laboratory. These tests demonstrated that two chutes could interrupt the same current as a single chute at double the voltage of a single chute. Cathode-ray oscillographic records illustrated a characteristic of particular interest, for they showed that the recovery voltage immediately following interruption divided equally between the two arc chutes. Within a very short interval this division was modified to values determined by the relative capacitances of the separate arc chutes and contact structures. The resistances of the continuous interleaving hot gas path across each chute immediately following interruption provided an efficient potential divider. It is this same resistance path in a single arc chutes that limits the rate of rise of recovery voltage immediately after current interruption. During a long history of tests on these breakers, this phenomena always has limited effectively the rate of rise of recovery voltage to 300 volts per microsecond or less, regardless of actual circuit characteristics.

In the art of circuit interrupters there are numerous instances where circuit breakers, inherently lacking in this desirable characteristic, have used external resistors to limit the rate of rise of recovery voltage to moderate values.

The length of the serpentine arc path can be increased by providing additional

Figure 2. Interleaving arc chutes for a 15,000-volt 250,000-kva Magne-Blast circuit breaker—one chute opened to show contour of interleaving fins

Figure 3 (left). Comparison of 15,000-volt and 7,500-volt Magne-Blast circuit breakers showing similarity of design features

Both breakers rated 250,000-kva interrupting capacity

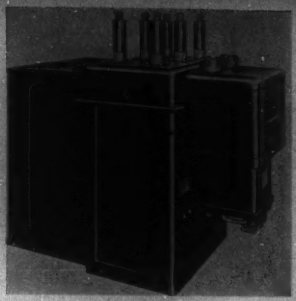
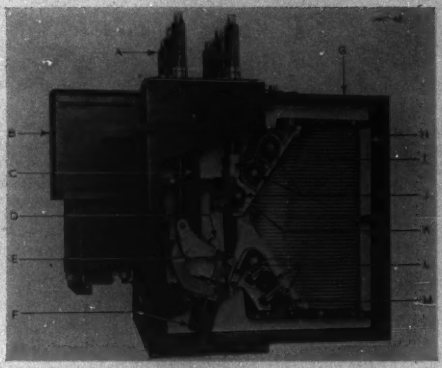


Figure 4

(a—right). 1,200-ampere Magne-Blast air circuit breaker for 15,000-volt service. Rated interrupting capacity 250,000 kva



(b). Cutaway view of circuit breaker through one pole showing arrangement of contacts, arc runners, series blowout coils, one side of interleaving arc chute, and muffler

A. Herkolite bushings
B. Solenoid operating mechanism
C. Operating rod
D. Primary contacts
E. Arcing contacts
F. Piston air booster
G. Removable box barrier
H. Muffler
I. Interleaving arc chute
J. Upper series blowout coils
K. Upper arc runner
L. Lower series blowout coils
M. Lower arc runner

or deeper fins. Increased fin depth is undesirable, as such a design necessarily dictates a wider chute. Here the efficiency of the magnetic system diminishes with the necessary increase in the gap spacing between the magnetic side plates or pole pieces. Additional fins, however, can be added without adding directly to the arc-chute size. Both thinner fins and a reduced spacing between fins add to the arc length directly without increasing the space requirements of the chute.

(*b*). The thermal effectiveness of the fins is increased also by moving the fins closer together, which flattens the normal cylindrical arc. The magnetic forces within the arc itself, however, try to return it to circular cross section which greatly increases the intimacy of the contact between the arc and fin surface. These phenomena are extremely effective in extracting heat from the arc. Figure 2 shows the interleaving arc chutes as developed for a 15-kv Magne-Blast breaker having 250,000-kva interrupting capacity. From this illustration the close proximity of the fins to the narrow interleaving path for the arc may be seen.

(*c*). As the thermal effectiveness of the fins is increased, the arc must be moved at correspondingly greater speeds to prevent excessive fin temperatures. The speed of the arc at any point, however, is proportional to the strength of the magnetic field at that point.

The strength of this magnetic field is a function of the current and the number of turns in the series blowout coils, the cross-sectional area of the iron-pole pieces, and the distance away from the coils. Six blowout coils are used to obtain a magnetic field of maximum flux density over the entire area of the arc chute. These coils are inserted one at a time as the arc travels along the diverging arc runners. Flux measurement tests have shown that, except for very small arc chutes, a much denser more uniform magnetic field can be obtained with several series coils distributed along the entire runner rather than by a single powerful series coil. This is due to the high values of flux leakage unavoidable in such large air-gap circuits, where the effective flux density reduces approximately as the square of the distance away from the coil. Superspeed photographs taken at the rate of 60,000 frames per second of actual arc interruptions also have shown that it is necessary to distribute these blowout coils to obtain uniform arc speed into the chute.

Design Features of the 15-Kv Breaker

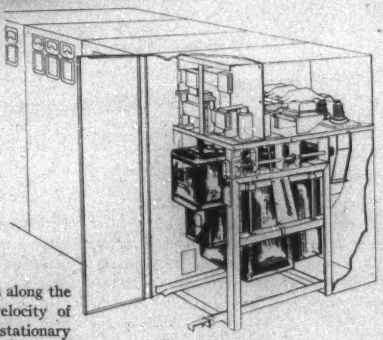
During the early stages in the development of this air circuit breaker for 15-kv service, a number of different arrangments of interleaving arc chutes were tested that varied considerably from those used on the original Magne-Blast-type circuit breaker. Although some of these designs were of early promise, none were so compact and so accessible as the conventional Magne-Blast arrangement. It is of interest that a revision of the original form of the Magne-Blast design was completely successful when the lengths of the arc path, thermal efficiency, magnetic field, and arc runner gap were scaled to satisfy the requirements for 15-kv service. Figure 3 illustrates the comparative sizes and design characteristics of one of the earliest (for 7,500-volt service) and the latest (for 15,000-volt service) circuit breakers of this type. All essential features are common to both ratings. The operating mechanism is still in an accessible position in front of the breaker; arc chutes and box barriers extend to the rear, and the entire unit is well adapted for vertical-lift metal-clad equipments. Figure 4*a* shows a 1,200-ampere 15-kv Magne-Blast breaker for 250,000 kva, and Figure 4*b* shows the cutaway cross section through one pole illustrating the arrangement of arc chutes, contacts, blowout coils, and so forth.

When the breaker is tripped the moment an arc is established, it leaves

(a—above). Circuit breaker and associated vertical-lift metal-clad switchgear unit

Figure 5

(b—right). Cutaway sketch showing circuit breaker elevated in place in metal-clad compartment



rupted, this magnetic driving force is always inherently weak when interrupting very light currents, particularly transformer magnetizing currents. To maintain the same high arc speeds and short arcing times when interrupting very light currents, as when interrupting heavy current, a supplemental air booster is provided as in the smaller breakers, but it is of increased size. This piston-type air booster is an integral part of the contact structure, and its effectiveness in maintaining short interrupting times during light-current interruptions can be seen in Figure 6, where a maximum of 4½ cycles for any value of short-circuit current is shown.

Test Data

Many extended series of interruption tests were made in the development of this breaker to obtain optimum co-ordination between the interleaving arc-path length, fin spacing, magnetic-field strength, and air-booster size. Table I shows a series of interruption tests taken on a production breaker, ranging from transformer magnetizing current values to values well above the interrupting rating of 250,000 kva. In no case did the total breaker operating time from trip impulse to interruption exceed 4.5 cycles. These tests were followed by several trip-free closing operations and several two-unit operation duty-cycle tests. The solenoid mechanism, designed for high closing speeds, practically eliminated arcing on closing operations. Figure 7*a* shows the magnetic oscillogram, and Figure 7*b* shows the cathode-ray oscillogram of a typical interruption test slightly above the 250,000-kva interrupting rating (test 51). The magnetic oscillogram shows the marked reduction in the short-circuit currents of each of the three phases as

the arcing contacts and travels along the arc runners at an average velocity of 75 feet per second. It is never stationary and moves too rapidly to do any appreciable burning on the surfaces of either the contacts or the runners. Deterioration is reduced so greatly that, even at the maximum interrupting current rating of 14,000 amperes, several hundred circuit interruptions may be completed without requiring maintenance or replacement of arcing surfaces. It was, therefore, desirable to design the contact structure and breaker mechanism with a mechanical life commensurate with this arcing surface life. A new design contact structure has been developed in which both the primary contacts and the arcing contacts pivot on silver-alloy washers. . . This construction eliminates entirely the need of any flexible braid connections. Fifty thousand mechanical operations made on this type of silver-ring pivot have shown it to be very resistant to wear. This long operating life provides a breaker which is suited just as ideally to industrial applications calling for highly repetitive operations, such as arc-furnace or rolling-mill motor control, as it is to central-station feeder protection where service continuity is the prime requisite.

As the magnetic-field strength available for driving the arc into the arc chute in any series-coil magnetic breaker is directly proportional to the current being inter-

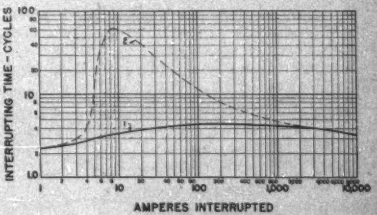
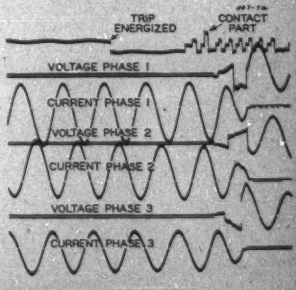


Figure 6. Interrupting time versus current of 15,000-volt Magne-Blast circuit breaker—rated 250,000 kva

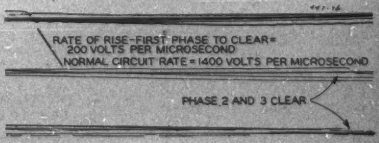
1. Interrupting time with air boosters
2. Interrupting time without air boosters

Figure 7

(a). Magnetic oscillogram of three-phase interrupting test at 270,000-kva, 14,500 volts. Test 51 of Table I. Note marked reduction of current due to arc resistance prior to interruption



(b). Cathode-ray oscillogram of recovery voltages across each pole following interruption of three-phase test shown in Figure 7*a*. Rate of rise is reduced from 1,400 volts per microsecond normal for this circuit to 200 volts per microsecond


RATE OF RISE-FIRST PHASE TO CLEAR = 200 VOLTS PER MICROSECOND
NORMAL CIRCUIT RATE = 1400 VOLTS PER MICROSECOND
PHASE 2 AND 3 CLEAR

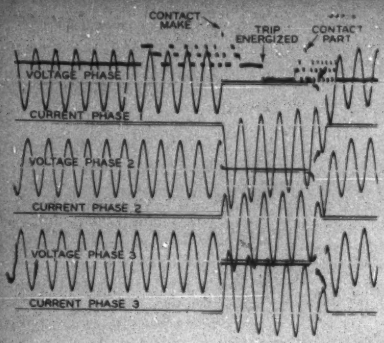


Figure 8. Magnetic oscillogram of three-phase trip-free closing–opening test at 310,000 kva 14,500 volts

Test 64*b*, Table I (second operation of two-unit operation duty cycle—15-second reclosing

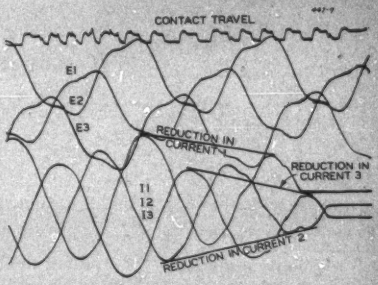


Figure 9. Magnetic oscillogram of three-phase opening test interrupting load current on high side of 6,000-kva 13,200-volt three-phase transformer supplying arc furnace

Note marked reduction of currents prior to interruption

the arc resistance increases. The normal circuit rate of rise of the recovery voltage of the first phase to clear on this circuit is 1,400 volts per microsecond. The resistance of the continuous interleaving hot gas path plus the advancement of the phase position of the current from the crest voltage point reduced the rate of rise of recovery voltage from the normal value of 1,400 volts per microsecond to approximately 200 volts per microsecond.

Figure 9 shows the oscillogram of a typical trip-free closing–opening operation at 310,000 kva. This is the second of a two-unit operation 15-second duty-cycle test 64*b*. These tests demonstrate the ample margin of safety of this breaker for application on 11,000- to 15,000-volt circuits requiring interrupting ratings up to 250,000 kva.

During an extended test series this breaker has demonstrated acceptable factors in reliability and in life. Exhaustive interruption tests have been but a portion of the complete test program. Tests for mechanical and load operations have established its operating life beyond 50,000 operations without the replacement of parts. Insulation tests meet all requirements. Since it was realized that arc-furnace applications represent a severe service duty, this breaker was placed temporarily on such service in a steel mill during its development. Complete field test equipment, with this temporary installation, provided a qualitative and quantitative analysis of breaker performance for such applications. The oscillograms taken during this investigation demonstrated the value of this type of an interrupter in controlling the rate of rise of recovery voltage when interrupting both the load currents and magnetizing currents of an arc-furnace circuit. Figure 9 shows the reduction in current prior to interruption of the breaker interrupting load current of a 13,200-volt 6,000-kva three-phase transformer supplying an arc furnace.

Conclusions

The established principles of the Magne-Blast-type circuit breaker can be extended beyond the range originally contemplated for this type of interrupter, as to both voltage and interrupting ability. The magnetic blasting of an arc into an interleaving chute can be controlled to cool and lengthen this arc at a rate necessary to interrupt the currents of a 250,000-kva rating at 15 kv. The proper co-ordination between arc-chute geometry, magnetic-field distribution and strength, and contact opening speed is used to create arc resistance at a rate most effective in completing efficient circuit interruption. The energy liberated by the arc is absorbed with a minimum of deterioration.

The advantages of the long electrical life of this breaker are combined with a sturdy mechanical design that insures reliability of service with a minimum of care and maintenance.

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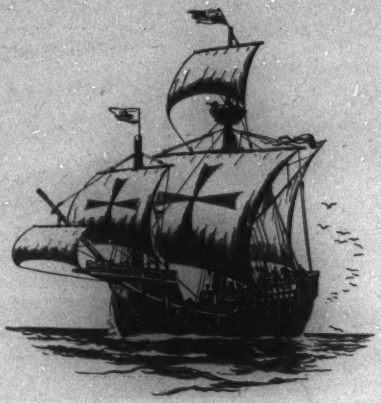

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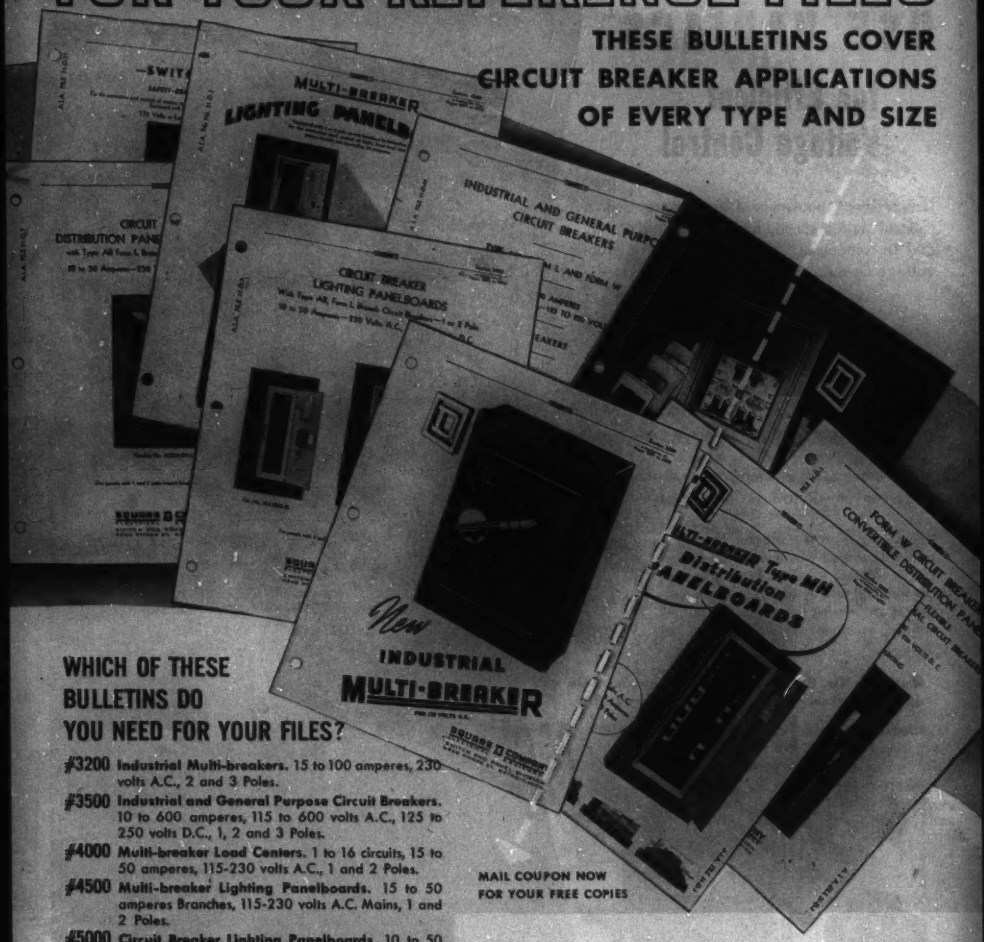

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#3000 **Square D Switchboards.** 575 volts A.C. or D.C.

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USE VARIACS*

for Efficient Voltage Control

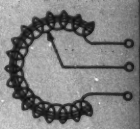
Hundreds of thousands of Variacs are used to control motor speed, heat, light and power, and to compensate for under-voltage or over-voltage lines.

Variacs have
- **LOW LOSSES**
- **GOOD REGULATION**
- **SMALL SIZE**
- **LINEAR VOLTAGE ADJUSTMENT**

These features, plus General Radio quality construction are the reasons for the wide acceptance of the Variac wherever variable a-c voltage is required.

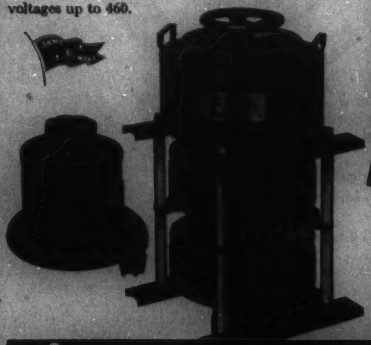
Variacs are more efficient, more economical, and more convenient to use than resistive controls.

The Variac is an autotransformer with a toroidally shaped winding. As the control dial is rotated, a carbon brush traverses the winding, turn by turn. The brush position at any setting determines the output voltage, which is read directly from the dial.



Bulletin No. 861 describes current models of the Variac. Write for your copy today.

Variacs are available for 60-cycle service in 9 models ranging from 170 va to 7 kva. They can be assembled in gangs for 3-phase operation in power ratings up to 25 kva for line voltages up to 460.



GR **GENERAL RADIO COMPANY** Cambridge 39, Massachusetts

NEW YORK CHICAGO LOS ANGELES

*The name Variac is a registered trade mark of the General Radio Company. The Variac is manufactured and sold under U. S. Patent No. 2,009,013.

PIPE LINE TO VICTORY

Up ahead the cluster of houses where the enemy had holed in crumbled. You could see the rubble flying high in the air and before the dust had settled could see other shells hit the mark.

Hunkered down in a shell hole, the observer pressed his lips closer to his phone's mouthpiece. "On target," he said . . . and his words went back across the rough terrain to the battery . . . came through clearly, distinctly.

That's because Laytex Assault Wire . . . made expressly for front line service . . . has a talking distance of better than five miles. It is a positive means of assuring clear, sure transmission of messages from reconnaissance posts to headquarters.

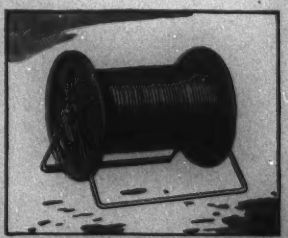
But talking distance is not the only advantage of Laytex Assault Wire. Its superior insulation makes possible its small diameter and light weight; a mile weighs less than 30 pounds. It has high resistance to moisture—can be unreeled over wet ground, through puddles and streams without affecting its efficiency. It is unaffected by temperature changes and does not become embrittled by concussion and shock

These same properties—light weight, small diameter, ability to withstand temperature changes, flexibility and toughness make other types of Laytex Wires and Cables as important in peacetime industry and building as to the Armed Forces.

Laytex US **ASSAULT WIRE**

ON THE JOB IN ANY CLIMATE. Laytex Assault Wire was developed by United States Rubber Company scientists working in close cooperation with engineers of the Army Signal Corps.

LIGHT WEIGHT SAVES MANPOWER. One man carries enough wire to keep communications open. This is important—it not only releases men for other duties but also reduces the fatigue of men who are travelling hard and fast.



TALKING DISTANCE...OVER 5 MILES . . . Laytex Assault Wire assures clear, sure transmission of messages—a prime military requirement for battlefront communications.

Listen to the Philharmonic-Symphony program over the CBS network Sunday afternoon, 3:00 to 4:30 E.W.T. Carl Van Doren and a guest star present an interlude of historical significance.

SERVING THROUGH SCIENCE TO BUILD A BETTER WORLD

UNITED STATES RUBBER COMPANY

1230 SIXTH AVENUE • ROCKEFELLER CENTER • NEW YORK 20, N. Y.

How to Select

INSULATING TAPES

Keep these facts in mind when selecting insulating tape:

A. The base cloth must: (1) have ample mechanical strength; (2) be chemically inert: (3) contain minimum sizing to permit thorough penetration by the insulating varnish and prevent weakening of the fiber in service.

B. The varnish must: (1) be neutral in relation to the cloth; (2) impart maximum dielectric strength, flexibility and resistance to heat, oil, water or other damaging agents against which the particular tape is to give protection.

C. A ready source of supply for all types of insulating tapes must be available. Your local G-E distributor handles a complete line of tapes, as well as all other insulating materials, and can furnish detailed data and catalog on request. Or send for catalog to Section M242-32, Resin and Insulation Materials Division, General Electric Company, Schenectady, N. Y.

GENERAL ELECTRIC

STRUTHERS-DUNN

INCORPORATED

5,288
TYPES OF
RELAYS

Each available in
countless coil combinations

CENTER CONTACT

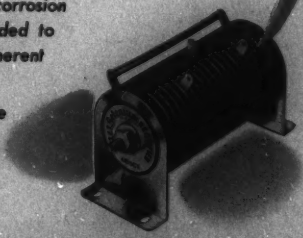
. . . New Federal Development Revolutionizes the Metal Rectifier!

By the use of a simple CENTER CONTACT *Federal has achieved another "first" in Selenium Rectifier development.*

The result — remarkable new corrosion resistance and weather stamina added to the important advantages already inherent in Federal Selenium Rectifiers.

Outstanding among these advantages are high efficiency over a wide range of load; small size and light weight; adaptability to wide ranges of temperatures, humidities and atmospheric pressures — plus maintenance-free operation.

CENTER CONTACT *is available only in Federal Selenium Rectifiers, first in the field and standard for industry.*



Federal battery chargers and power supplies, powered by Selenium Rectifiers, have wide application in the fields of radio, telephone, telegraph, aviation, railway signaling and wherever direct current is required from an AC source.

Federal Telephone and Radio Corporation

An IT&T Associate

Newark, N. J.

How to keep posted on Tubes!

WITH the RCA TUBE HANDBOOK on your desk, you have available at all times, and in concise, handy form, the most up-to-date technical data for each tube in RCA's comprehensive tube line...plus a wealth of detailed information such as the Army-Navy Preferred Tube list; definitions of general terms; tube ratings and their significance; types of cathodes and their use; outline-, base-, and cap-drawings; classification charts of receiving, power, and cathode-ray tubes; resistance-coupled amplifier chart; list prices; etc.

The $6.00 subscription price* brings you not only the two 7⅛" x 5" binders finished in black fabricoid and imprinted in gold, complete with data sheets, but *also* additional sheets containing new and/or revised data as issued during the year! Annual service fee thereafter, $1.50.

Fill out (or copy) Subscription Order Form shown below, and mail it with your check today. This is the *only* way for you to make sure of having the same completely up-to-the-minute and authoritative information about RCA tubes . . . exactly when and where you want it...that thousands of other electronics engineers are using every day. RADIO CORPORATION OF AMERICA, *Commercial Engineering Section, Harrison, New Jersey.*

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TWO VOLUMES—6 SECTIONS

(approximately 1,500 pages)

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TRANSMITTING TUBES
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Data sheets for each tube type include: (a) intended uses; (b) maximum ratings; (c) characteristics; (d) typical operating conditions; (e) physical dimensions; (f) terminal connections; and (g) the most commonly used curves plotted to easily readable scales and large enough for solving design problems.

Convenient loose-leaf form • Kept up-to-date • Comprehensive data
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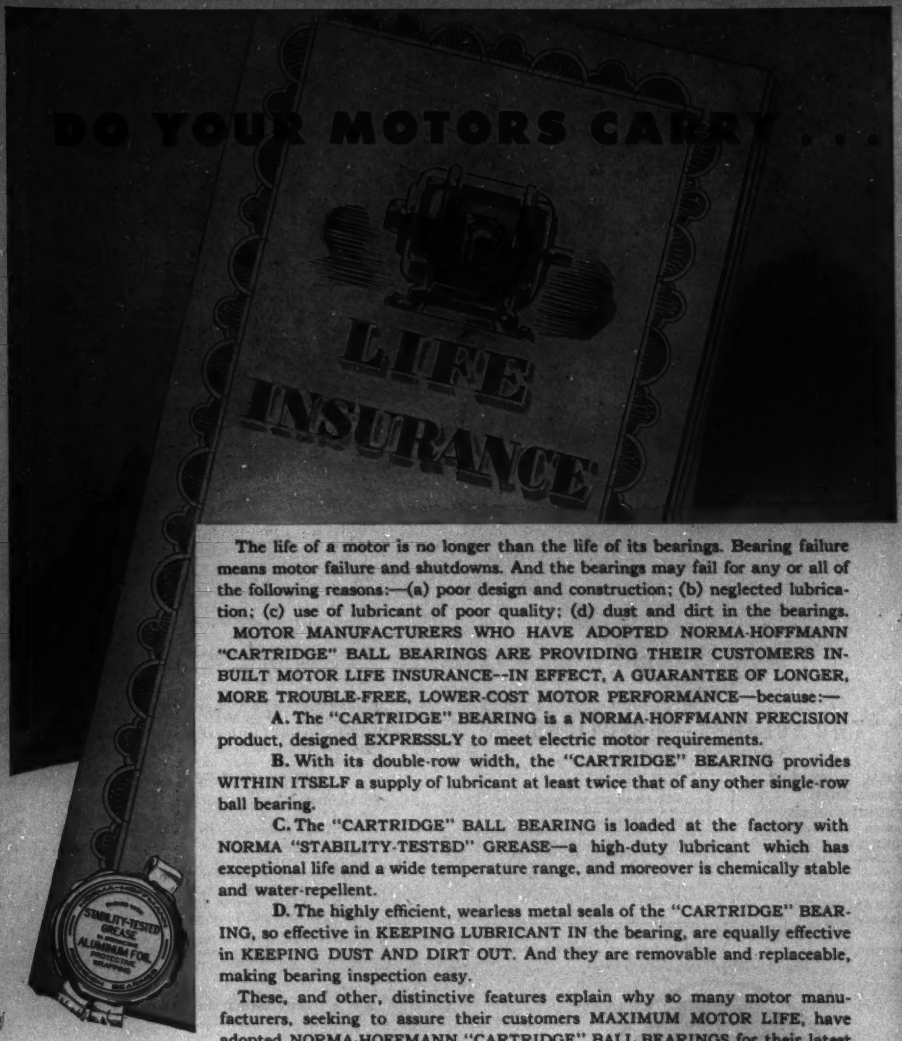


The life of a motor is no longer than the life of its bearings. Bearing failure means motor failure and shutdowns. And the bearings may fail for any or all of the following reasons:—(a) poor design and construction; (b) neglected lubrication; (c) use of lubricant of poor quality; (d) dust and dirt in the bearings.

MOTOR MANUFACTURERS WHO HAVE ADOPTED NORMA-HOFFMANN "CARTRIDGE" BALL BEARINGS ARE PROVIDING THEIR CUSTOMERS IN-BUILT MOTOR LIFE INSURANCE--IN EFFECT, A GUARANTEE OF LONGER, MORE TROUBLE-FREE, LOWER-COST MOTOR PERFORMANCE—because:—

A. The "CARTRIDGE" BEARING is a NORMA-HOFFMANN PRECISION product, designed EXPRESSLY to meet electric motor requirements.

B. With its double-row width, the "CARTRIDGE" BEARING provides WITHIN ITSELF a supply of lubricant at least twice that of any other single-row ball bearing.

C. The "CARTRIDGE" BALL BEARING is loaded at the factory with NORMA "STABILITY-TESTED" GREASE—a high-duty lubricant which has exceptional life and a wide temperature range, and moreover is chemically stable and water-repellent.

D. The highly efficient, wearless metal seals of the "CARTRIDGE" BEARING, so effective in KEEPING LUBRICANT IN the bearing, are equally effective in KEEPING DUST AND DIRT OUT. And they are removable and replaceable, making bearing inspection easy.

These, and other, distinctive features explain why so many motor manufacturers, seeking to assure their customers MAXIMUM MOTOR LIFE, have adopted NORMA-HOFFMANN "CARTRIDGE" BALL BEARINGS for their latest and most efficient motor models.

Ask for motors carrying the "life insurance" that NORMA-HOFFMANN "CARTRIDGE" BEARINGS provide. They will be a sound and lasting investment, returning good dividends in lower costs, longer life, and freedom from shutdowns.

NORMA-HOFFMANN BEARINGS CORP'N, STAMFORD, CONN. FOUNDED 1911

TO WIN THE WAR • WORK • FIGHT • BUY WAR BONDS

In these two compact units there are really seven instruments

There are only three standard *-hp-* instruments included in this laboratory set-up yet the two units include the following seven: an *-hp-* Resistance-Tuned Audio Oscillator, an attenuator, a vacuum tube voltmeter, a set of fundamental elimination filters, an input meter, an output meter, and a wave analyzer. The uses for this combination of instruments are too extensive to list here but some idea of its scope is shown by the following:

- **Measure voltage level, power output and amplifier gain.**
- **Measure noise and hum level in audio frequency equipment.**
- **Measure individual components of a complex wave.**
- **Measure voltages from 3mv to 300v—from 10cps to 100kc.**
- **Measure total distortion of frequencies from 30cps to 15kc.**
- **Integrate noise spectrum for acoustic measurements.**
- **Generate a known voltage as well as a known frequency at common impedance levels and make many another test or measurement on audio frequency equipment.**

Remember! The *-hp-* audio oscillator (in 205AG) requires no zero setting, the Model 300A wave analyzer provides variable selectivity, *-hp-* vacuum tube voltmeter indication is proportional to the average value of the full wave and the *-hp-* Audio Signal Generator makes standardized frequencies and voltage instantly available. Get full information about these and other outstanding *-hp-* electronic instruments today. Ask for the new 24-page catalog which gives much valuable information in addition to complete data on *-hp-* instruments.

HEWLETT-PACKARD COMPANY

805 Box 805, Station B, • Palo Alto, Calif.

RATING DATA

Voltage and Wattage Ratings:—

	TYPE 1 Maximum Wattage Rating	R.M.S. Voltage Rating
Resistance Value		
Up to 1.9 megohms	12 watts	based on wattage
2.0 to 10 megohms	9 watts	9 kv. max.
Above 10 megohms	based on voltage	10 kv. max.

	TYPE 2 Maximum Wattage Rating	R.M.S. Voltage Rating
Resistance Value		
Up to 3.9 megohms	22 watts	based on wattage
4.0 to 20 megohms	15 watts	15 kv. max.
Above 20 megohms	based on voltage	20 kv. max.

Temperature Rating:—
Maximum recommended hot spot temperature for continuous operation: 130°C (Ambient plus rise).
Maximum recommended ambient temperature for full wattage ratings: 70°C.

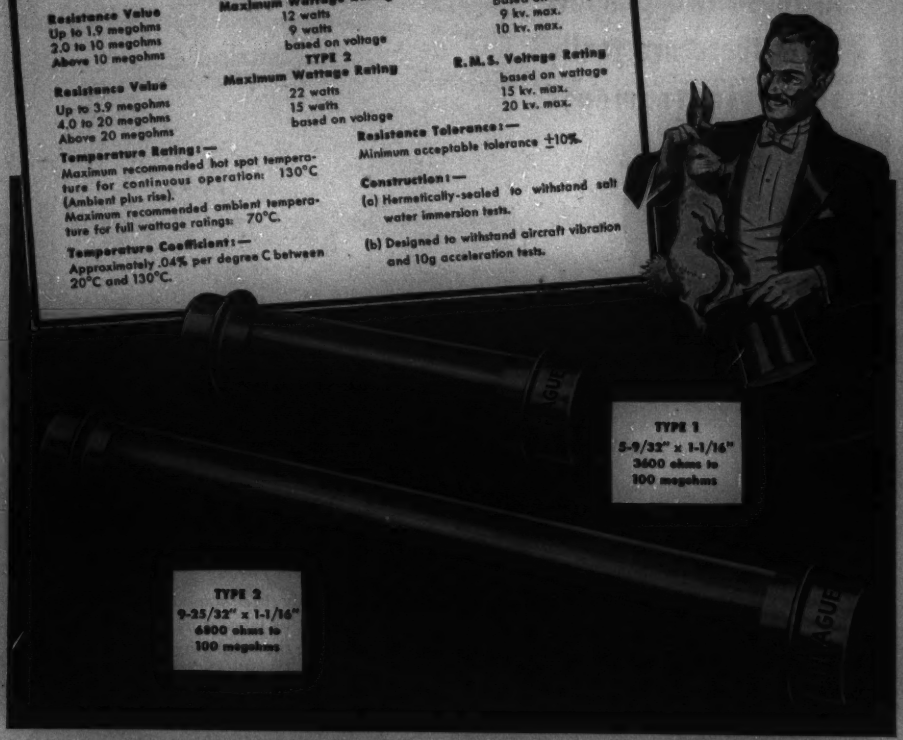
Temperature Coefficient:—
Approximately .04% per degree C between 20°C and 130°C.

Resistance Tolerance:—
Minimum acceptable tolerance ±10%.

Construction:—
(a) Hermetically-sealed to withstand salt water immersion tests.

(b) Designed to withstand aircraft vibration and 10g acceleration tests.

A problem solved, designed, and produced in ninety days—and made possible by long-standing research and experience.



TYPE 1
5-9/32" x 1-1/16"
3600 ohms to
100 megohms

TYPE 2
9-25/32" x 1-1/16"
6800 ohms to
100 megohms

SPRAGUE MEG-O-MAX
HIGH-RESISTANCE, HIGH-VOLTAGE RESISTORS

Less than 3 months from the presentation to Sprague Koolohm Resistor engineers of the problem of designing high-resistance value units capable of dissipating power at voltages up to 20 kv. and at high ambient temperatures, the first Sprague Meg-O-Max Resistors were on the job! Moreover, they used practically no critical materials, were of smaller physical size, and presented a degree of resistance stability and mechanical ruggedness not available in other units, exclusive of costly wire-wound meter multiplier types!

Entirely unique in construction, Meg-O-Max Resistors are formed of a series of molded segments. These are joined non-inductively, and the assembly is then encased in a hermetically-sealed, rugged glass envelope provided with ferrule terminals to withstand aircraft vibration tests, salt water immersion tests, and tests for mechanical shock produced by rapid acceleration.

In addition to use as a high-voltage bleeder and as a broad accuracy meter multiplier for a voltage indicator, Meg-O-Max Resistors find many applications in measuring instruments, rectifier systems, high-voltage dividers, and as broad accuracy meter multipliers. Specify Meg-O-Max for High-Resistance—High-Voltage requirements.

Data sheets gladly sent upon request. Samples sent only on firm's request, giving details of application.

SPRAGUE SPECIALTIES COMPANY
Resistor Division • North Adams, Mass.

A NEW DEVELOPMENT BY THE MAKERS OF **KOOLOHM** INSULATED WIRE-WOUND RESISTORS
TRADEMARK REGISTERED

Another Example of the Use of Ohmite Close-Control Rheostats in the Production Tools of War!

THIS boring mill, *built for fast machining of Tank Turrets*, was designed by The Consolidated Machine Tool Corp. To facilitate and speed up the machining operation, it was important that the adjustable speed drive have a wide range of speed control—and that the controls be so simple and compact that even untrained workers could quickly learn to run the machine.

A system of speed adjustment by voltage control developed by the Reliance Electric and Engineering Company was used. In this system, smooth, accurate voltage control of the feed motor generator is obtained by the use of two Ohmite taper-wound Model "R" Rheostats as shown in the view of the control station below. One section of the tandem unit is connected into the generator field circuit and the other section into the field of the feed drive motor. With a combination of the electrical feed drive and two gear shifts, one of which provides for rapid traverse, the feed range is .0035 inch to 5½ inches per minute.

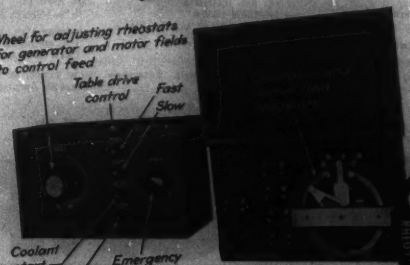
This is another example of the use of Ohmite Close-Control Rheostats in the Production Tools of War—as well as in planes, tanks, ships and war communications equipment.

Ten wattage sizes from 25 to 1000 watts, in straight or tapered winding, in single or tandem units. Ohmite Engineers are glad to work with you on any resistance-control problem.

Send for Catalog & Engineering Manual No. 40

Write on company letterhead for this helpful 96-page guide in the selection and application of Rheostats, Resistors, Tap Switches.

OHMITE MANUFACTURING CO.
4863 Flournoy Street, Chicago, U. S. A.



GET YOUR COPY NOW!

Complete catalog listings, dimension diagrams of every unit, up-to-the-minute engineering data on fixed and variable resistors for radio and other electronic uses, iron cores of all types, and inexpensive slide, line, and rotary-action switches. . . .

That's the story of this new 36-page Stackpole Electronic Components Catalog, just off the press. Write, wire or ask your Stackpole District Engineer for a copy today. Please ask for Catalog R6.

THESE ELECTRONIC DIVISION ENGINEERS TO SERVE YOU

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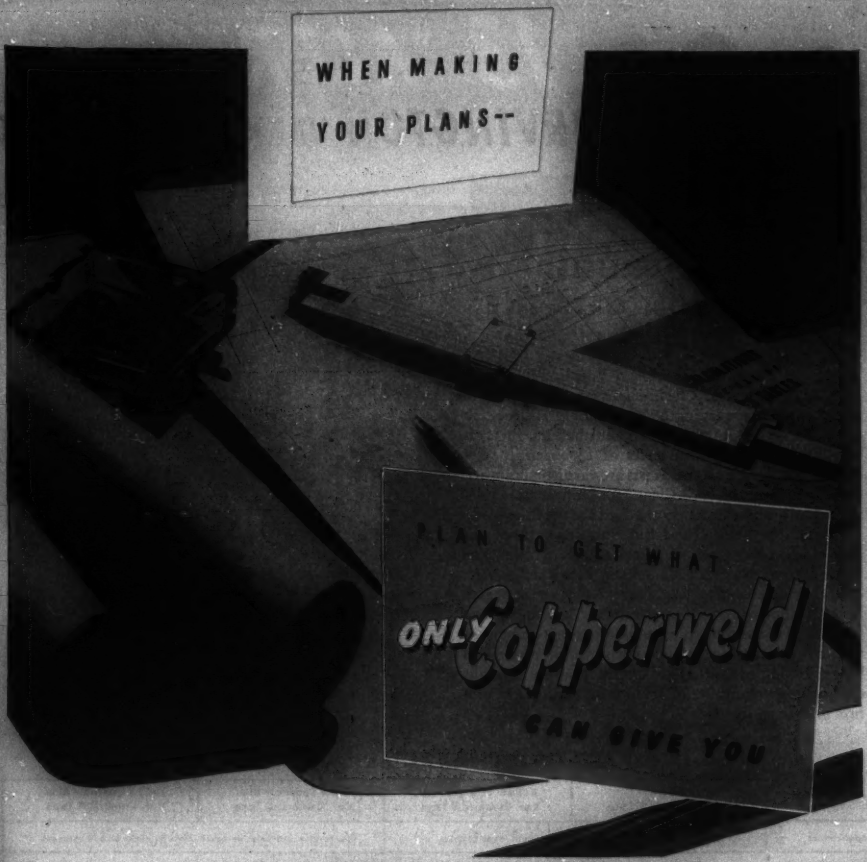
STACKPOLE CARBON CO., ST. MARYS, PA.

STACKPOLE

ELECTRONIC COMPONENTS



It goes without saying that our Number One job is to win the war. But future-minded executives and engineers in the telephone and telegraph companies, in the electric light and power companies, and in the railroads, realize that there is no priority on careful planning. In the midst of today's exacting demands, plans are accumulating for necessary replacements, improvements, and extensions as soon as conditions permit.

In your evaluation of materials, plan to get the performance qualities that only Copperweld can give you—the *combination* of the best characteristics of both steel and copper. In steel you get strength. In copper you get high electrical conductivity and rust resistance. In Copperweld you get the best characteristics of both metals permanently molten-welded for top performance.

Our representatives throughout the country are at your service. Call upon them when you are making your plans.

COPPERWELD STEEL COMPANY · GLASSPORT, PA.

13 "ALERTS" TEST IRVINGTON VARNISHED CAMBRIC

ONLY QUALIFIED INSULATION GETS THE "ALL CLEAR"

In the production of Irvington Varnished Cambric and Tape, laboratory technicians are ever "on the alert" to maintain Irvington's high standards for electrical insulation. Raw fabric and finished product are regularly subjected to a series of 13 exacting tests. Only after passing all these tests are varnished cambric and tape given the "All Clear" for shipment.

Carefully and constantly checked are the following: Construction, purity, and bursting strength of the base cloth; uniformity of thickness, elongation, and tensile strength of both base and varnished fabric; dielectric strength, tear strength, and resistance to heat and hot oil of finished cambric and tape. The severity of these tests, plus manufacturer's control of varnish formulation, is your assurance of better and longer lasting insulation—of quality that has brought confident, growing use of Irvington Varnished Cambric and Tape for over 38 years.

Running test of heat resistance of varnished cloth is observed on a test machine. Samples of cloth are being checked for strength, resistance and elasticity.

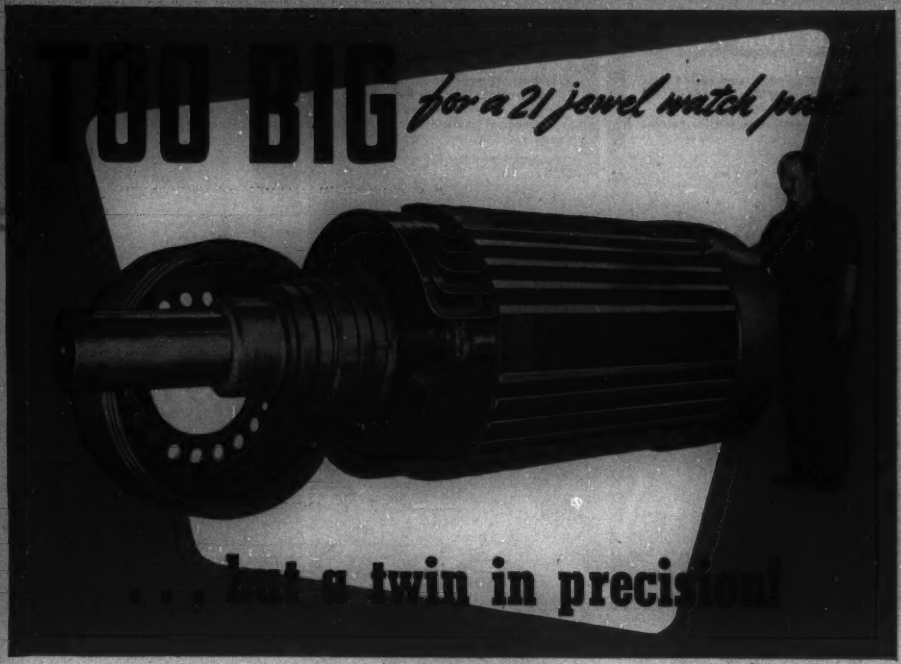
COMPARATIVE CHARACTERISTICS CHART

	Black Straight Cut Var. Cambric & Tape	Yellow Straight Cut Var. Cambric & Tape	Black Seamless Bias Var. Cambric & Tape	Yellow Seamless Bias Var. Cambric & Tape
Applications	For hand or machine taping of straight, even surfaces		For hand or machine taping of irregular surfaces and contours	
General Properties	Resistant to abrasion, aging, heat, water, acid and alkalies; smooth and flexible.			
Special Properties	Resistant to lubricating oil	Resistant to insulating oil	Resistant to lubricating oil Elongation — — 1.7% @ 20 deg. C. (.010" Th.)	Resistant to insulating oil Elongation — — 1.5% @ 20 deg. C. (.010" Th.)
Dielectric Strength (.010" thickness) volts per mil	1050	950	As received — 1000 After elongation — 800	As received — 900 After elongation — 575
Tensile Strength (.010" thickness) — lbs. per 1" width	40	38	38	35
Indicated Uses	On corners and between layers of field coils; for phase insulation of stators; as slot insulation; and for overall coil wrappings	For wrapping small coils and coil forms; as insulation between windings of ignition, magneto and transformer coils, as slot, and winding and phase insulation.	Where tight, smooth lap winding is required as on armature and field coils; for bus bar and terminal insulation; for taping cable joints and connections.	Especially suitable for transformer and other coils which operate in insulating oil; armature, field and other coils involving angles and bends.

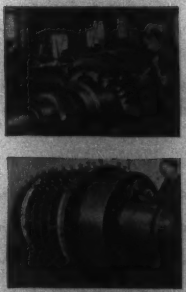
For additional information or samples, write Dept. 38

IRVINGTON VARNISH & INSULATOR CO.
Irvington, New Jersey, U.S.A.
Plants at Irvington, N. J. and Hamilton, Ontario, Canada

IRVINGTON *Electrical* INSULATIONS

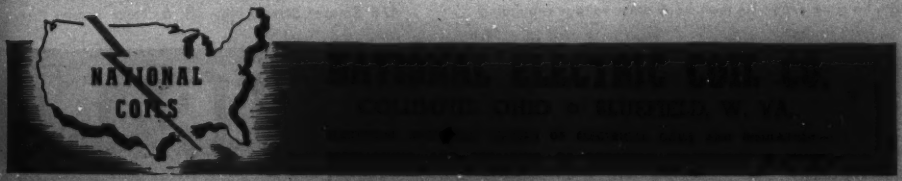


If the balance-staff of your 21-jewelled watch were a foot in diameter it would almost equal the size of the shaft of the alternator field pictured here. Large as it is, the alternator is as truly a precision instrument as is the watch. ¶ Sent to National for rewinding, it is now back on the job . . . a source of electrical energy as thoroughly dependable as the day it was first installed. An example of the dependency which power plants, mines, railroads and industry generally, here and abroad, place in National skill and workmanship. Two plants, each splendidly equipped and manned. Get National dependability and precision in *your* rotating electrical equipment when modernizing or repairing is needed.



LARGE ALTERNATOR REWOUND

Shown is a typical large alternator field rewound in our Columbus plant. Weight 60,000 lbs., peripheral speed 24,800 FPM (4.68 miles per minute).



PRECISE A.C. VOLTAGE CONTROL

WITH LOW CURRENT CONSUMPTION

For a continuously adjustable voltage or a constant voltage from a fluctuating source, specify Transtat A.C. Voltage Regulators. Their velvety smooth, practically stepless control is unmarred by current interruptions, arcing or line surges. They operate with high electrical efficiency and cannot reduce power factor or distort wave form. With a range from 0 to 100% rating, they may also be connected to provide higher than line voltages. Yet Transtats are no more expensive than many other voltage regulating devices. Write today for complete information covering manual, motorized and fully automatic Transtats. Ask for bulletin 51-2U.

• Cutaway view of a typical TH Transtat showing both outside case and arrangement of parts inside case.

★

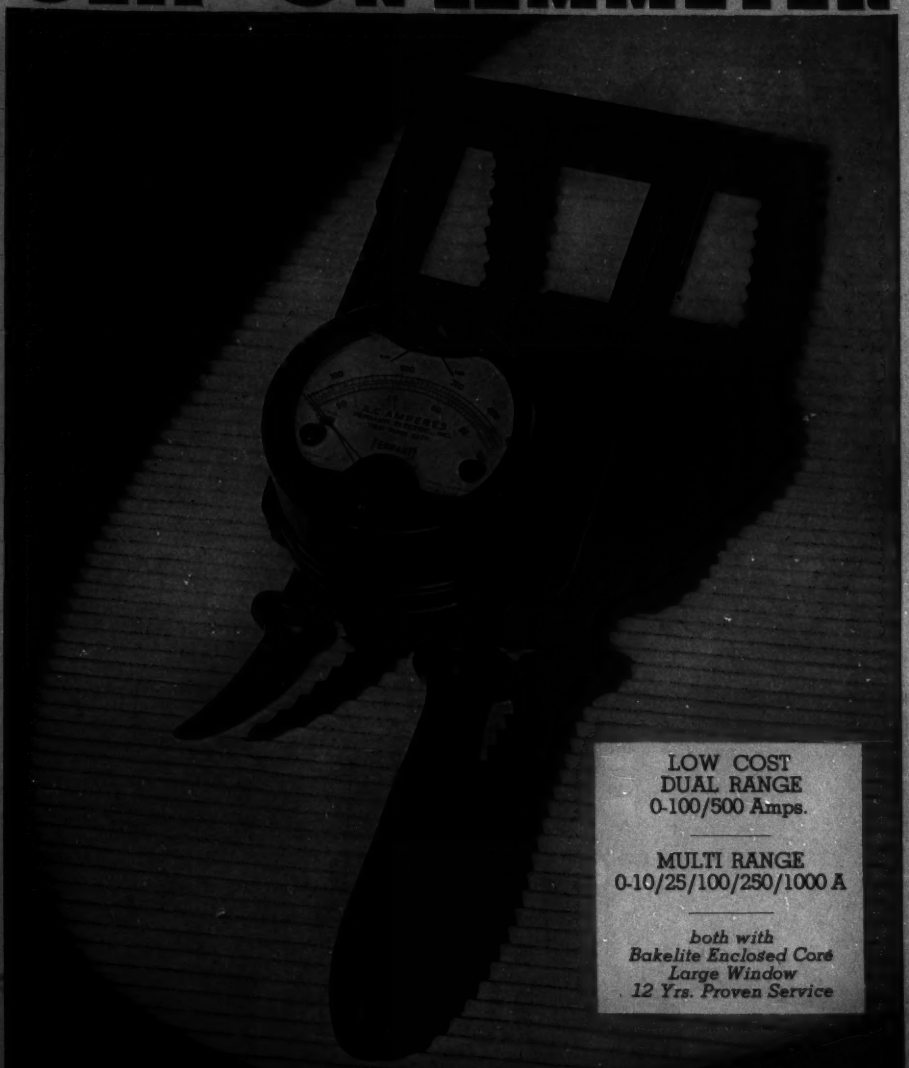
AMERICAN TRANSFORMER COMPANY

178 Emmet Street, Newark 5, New Jersey

Pioneer Manufacturers of Transformers, Reactors and Rectifiers for Electronics and Power Transmission

AMERTRAN

CLIP-ON AMMETER



LOW COST
DUAL RANGE
0-100/500 Amps.

MULTI RANGE
0-10/25/100/250/1000 A

both with
Bakelite Enclosed Core
Large Window
12 Yrs. Proven Service

FERRANTI ELECTRIC, INC. 30 ROCKEFELLER PLAZA NEW YORK, N. Y.

Ferranti Electric, Ltd., Toronto, Canada • Ferranti, Ltd., Hollinwood, England

The magic of ELECTRONICS...

No word in industry has achieved more fame than "electronics". Perhaps its excessive use has over emphasized the wonders of an electronic world. However, there is the undeniable fact that the magical performance of electronic equipment is unexcelled.

An outstanding example is the SECO automatic voltage regulator. When its electronic "genie" . . . a special bridge and thyratron tube circuit . . . detects any fluctuation in A-C line voltage, a variable voltage transformer is authorized to correct for a constant output voltage.

This improved type regulator retains all the desirable characteristics inherent in the variable voltage autotransformers.

- HIGH EFFICENCY — 98% or better at full load.
- NO WAVE FORM DISTORTION.
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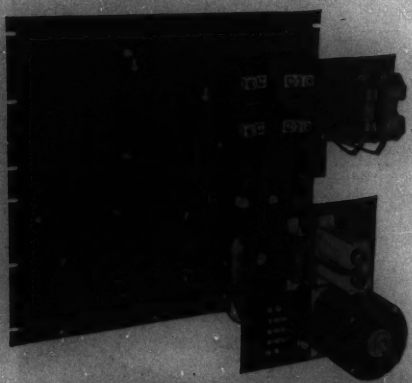

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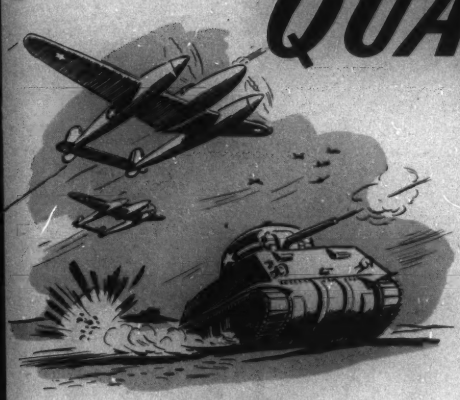

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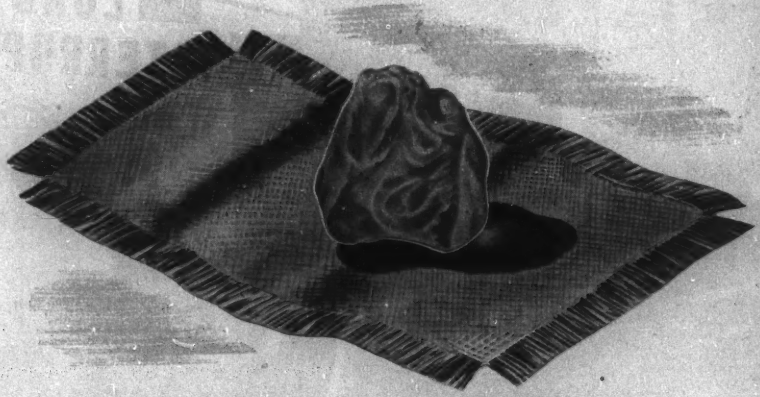

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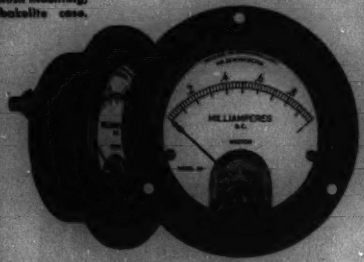

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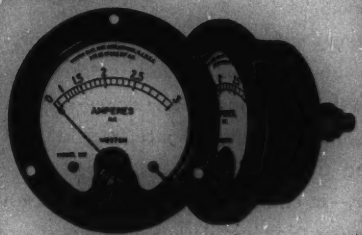

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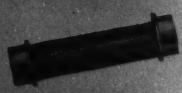

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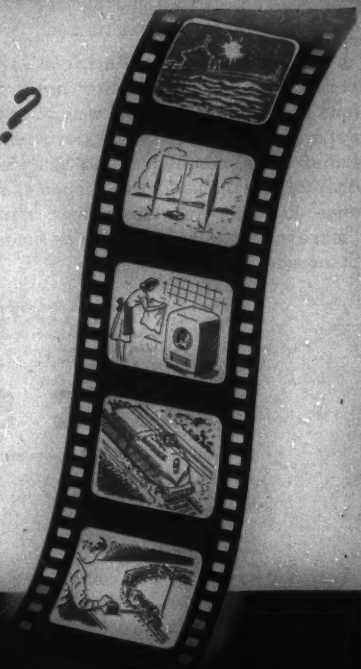

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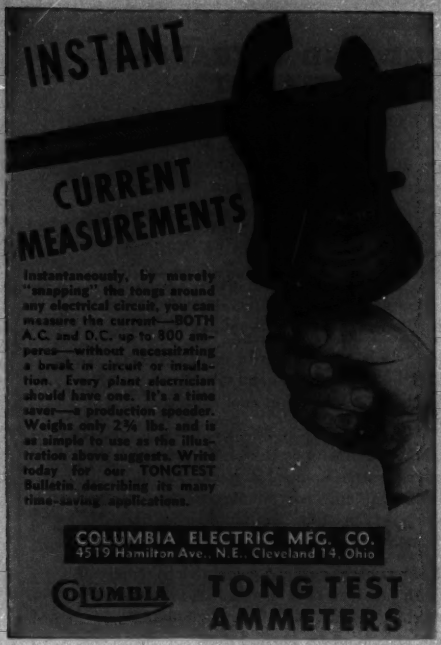
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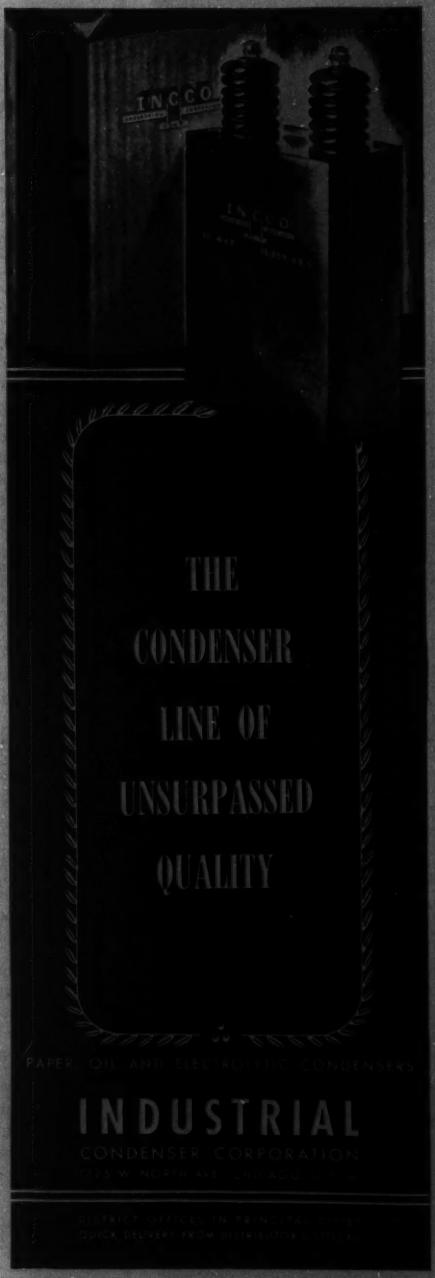

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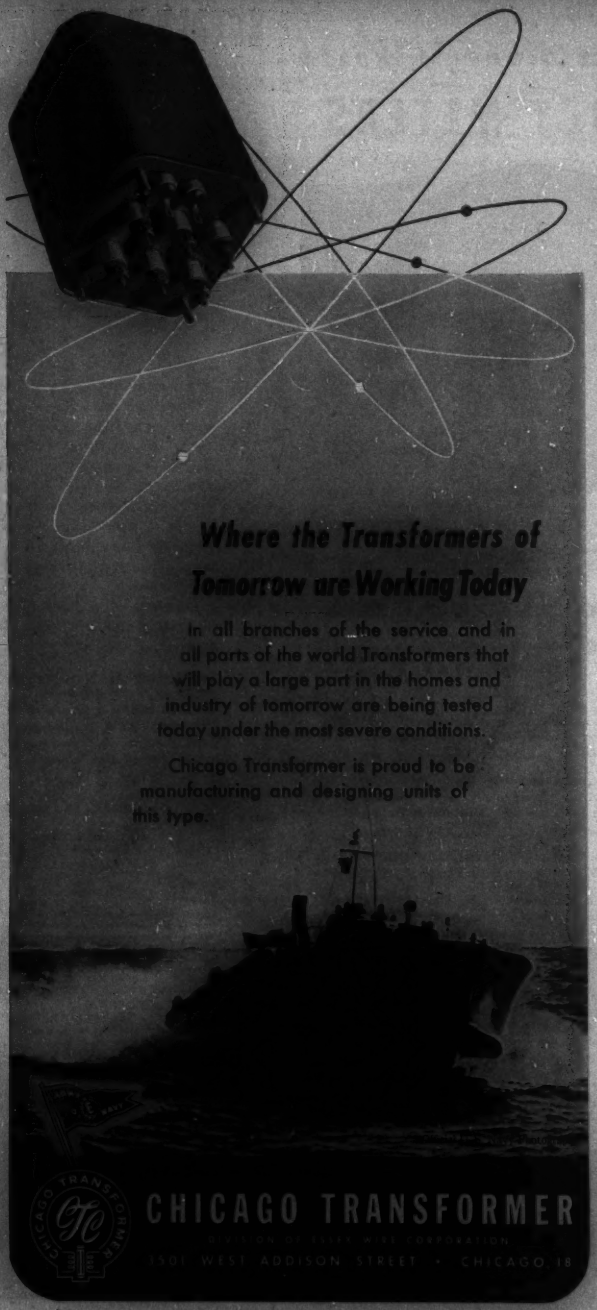
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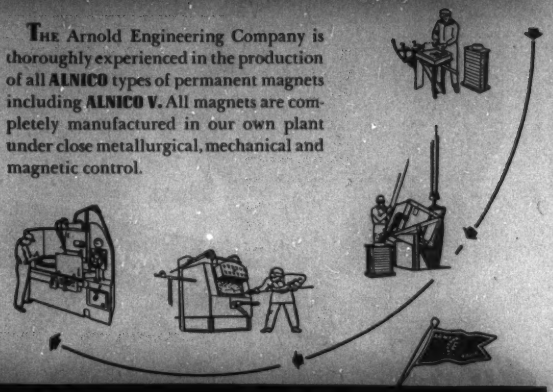

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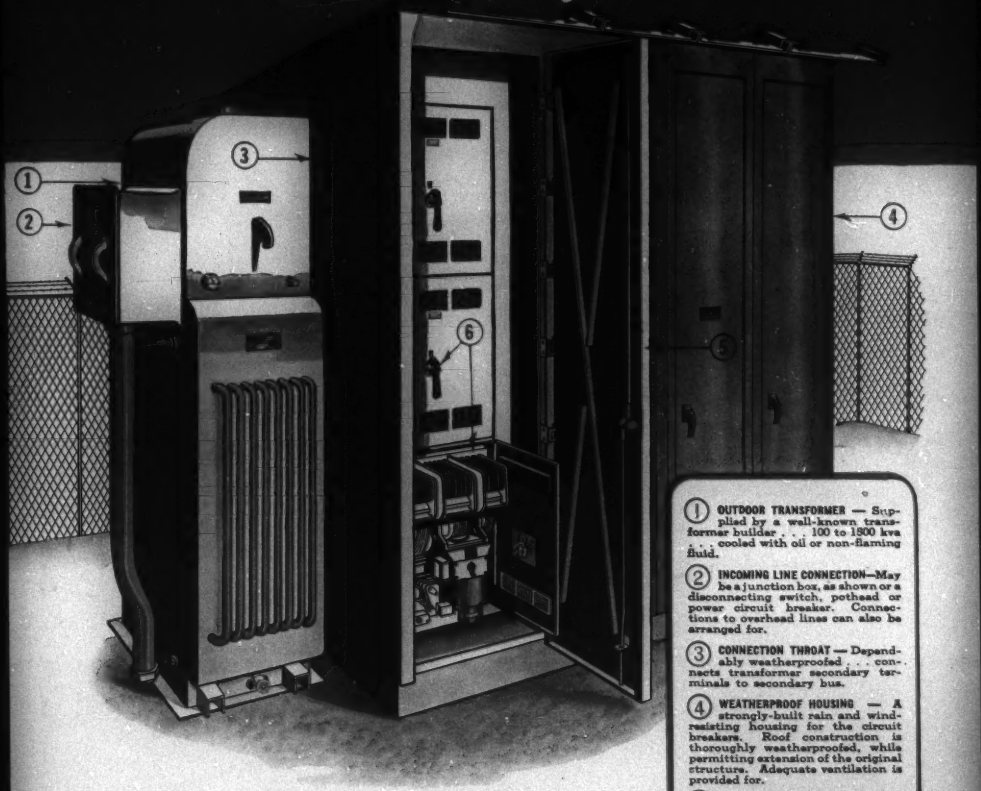

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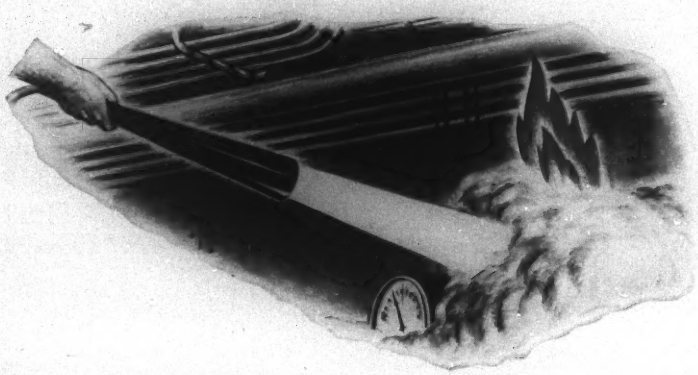

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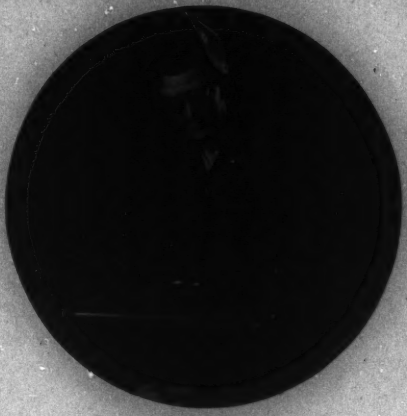

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ALLIS-CHALMERS AMPAC "400"

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April 1944, Vol 63, No. 4. Number of copies of this issue 26,000